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TWO

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Welcome

September 2012

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you'll find an exclusive feature on egyptology



Not so long ago, it was said that you could squeeze all the bones of ancient humans ever discovered into one suitcase. Today, they'd fill several. That's

still not many bones, but it's what you do with them that counts. In this issue, Dr Isabelle De Groote of the Natural History Museum reveals just how much we can piece together about our ancient ancestors using the latest forensic techniques. Isabelle was a consultant on Alice Roberts' new BBC series *Prehistoric Autopsy*, which airs in the autumn. Until then, turn to page 34 to take a journey into our past.

A different kind of journey was made recently by another TV presenter – the oceanographer and physicist Dr Helen Czerski. With co-presenter Chris Packham and a BBC film crew, Helen set sail for Arctic waters in search of an iceberg breaking off from the polar ice sheet. The expedition was a scientific first to understand the incredible forces of nature involved and to find out what happened to the 'berg afterwards. On page 49, Helen reports on stage one of the trip. You can see her entire journey by tuning in to BBC Two later this year.

In future, icebergs may not be the only objects bobbing around the world's oceans. There might be floating cities, too. It sounds like a flight of fancy, and certainly some of the designs could grace the covers of sci-fi novels. But a couple of organisations are raising serious funds to make it a reality. Paul Parsons investigates whether it might actually be feasible on page 60.

Sticking with futuristic themes, the release of a new movie version of *Total Recall* makes this month the perfect time to think about memory. Specifically, is it possible to alter a person's memories, or create new ones? Psychologist Charles Fernyhough investigates on page 54.

There's much else besides, including our review of the new Raspberry Pi computer (p88). When I was young, I remember writing simple programs in BASIC for the Acorn Electron, cousin of the famous BBC Micro. If the Raspberry Pi does the same for today's schoolkids, it might just inspire a whole new generation of programmers.

Until next issue,

Graham

What I've found out this month

- In California, a second-hand cruise liner could be the first true 'seasteed' (p60)
- All the gold mined throughout history would fit into a square box with sides of around 20m in length (p80)
- Seen from Io, planet Jupiter would appear the size of 40 full Moons (p70)

Experts



Dr Helen Czerski
Helen is an oceanographer and physicist at the University of Southampton. Soon to be seen in the BBC Two programme *Operation Iceberg*, she also co-presented *Orbit: Earth's Extraordinary Journey*.



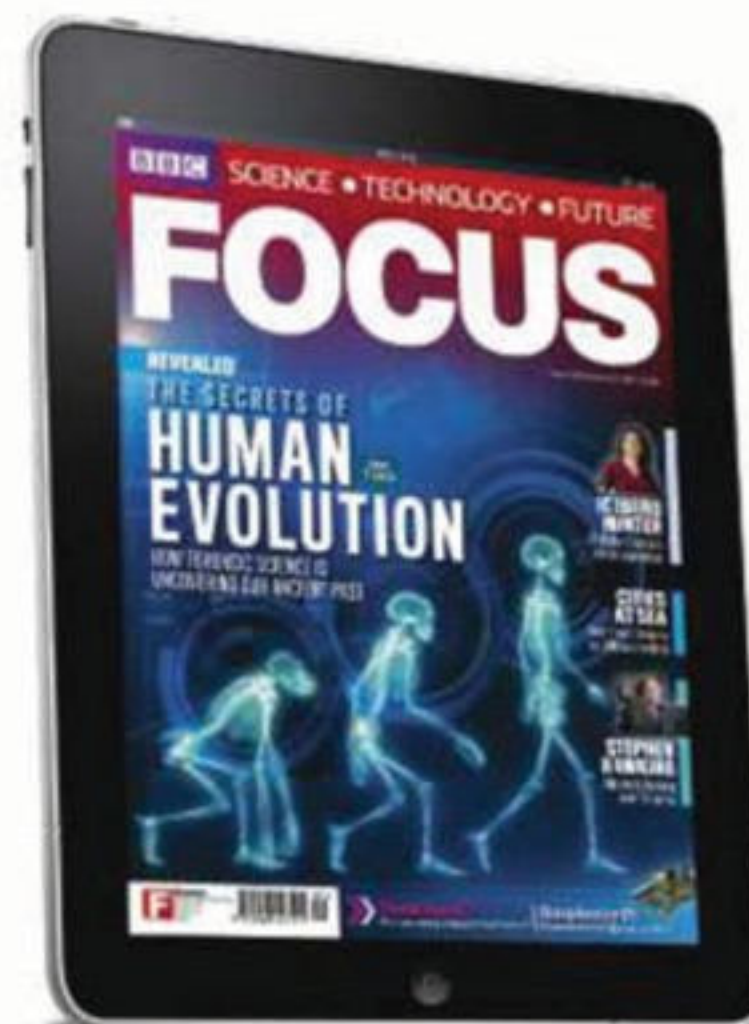
Dr Matthew Chalmers
Matthew has a PhD in physics and became a science journalist after a stint in the financial sector. On p43 he looks at how lightning is being created in a lab to keep tomorrow's aircraft safe.



Dr Charles Fernyhough
Writer and academic Charles has a PhD in developmental psychology and is the author of *Pieces Of Light: The New Science Of Memory*. He asks whether it's possible to erase or implant memories on p54.



Dr Isabelle De Groote
Isabelle is a palaeoanthropologist specialising in Neanderthals. A consultant for the BBC series *Prehistoric Autopsy*, on p34 she reveals the physical features that made our ancestors successful.



Focus iPad edition

Exclusive to September's App:

- Hear Prof Alice Roberts describe the anatomy of our ancient ancestors
- Watch NASA's Curiosity rover descend to the surface of Mars
- See the car headlights that make rain vanish



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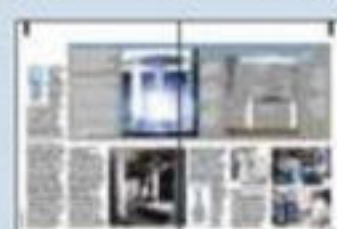
Among the top science stories: ancient DNA is brought back to life and Curiosity snaps Mars



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We report from the 'lightning lab', where artificial bolts are generated to protect future planes



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COVER STORY As part of a new BBC series, Helen Czerski joins a scientific mission to the Arctic ice



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COVER STORY The mind-manipulation of the film *Total Recall* is becoming a reality



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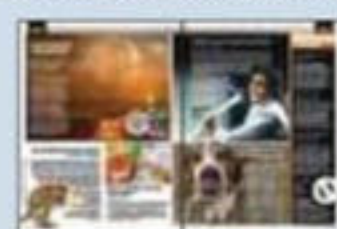
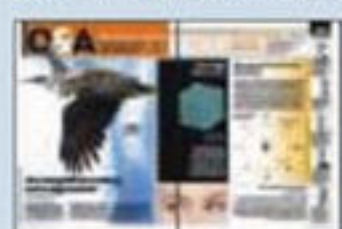
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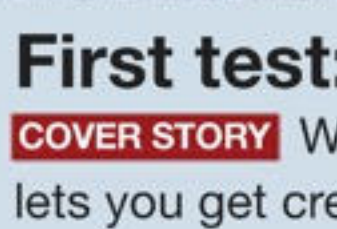
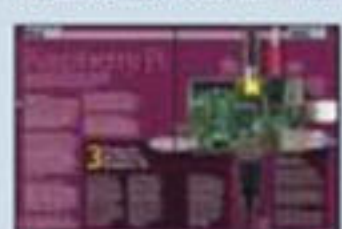
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The YouView set-top box, a remote-controlled submarine, a biometric coffee machine and more



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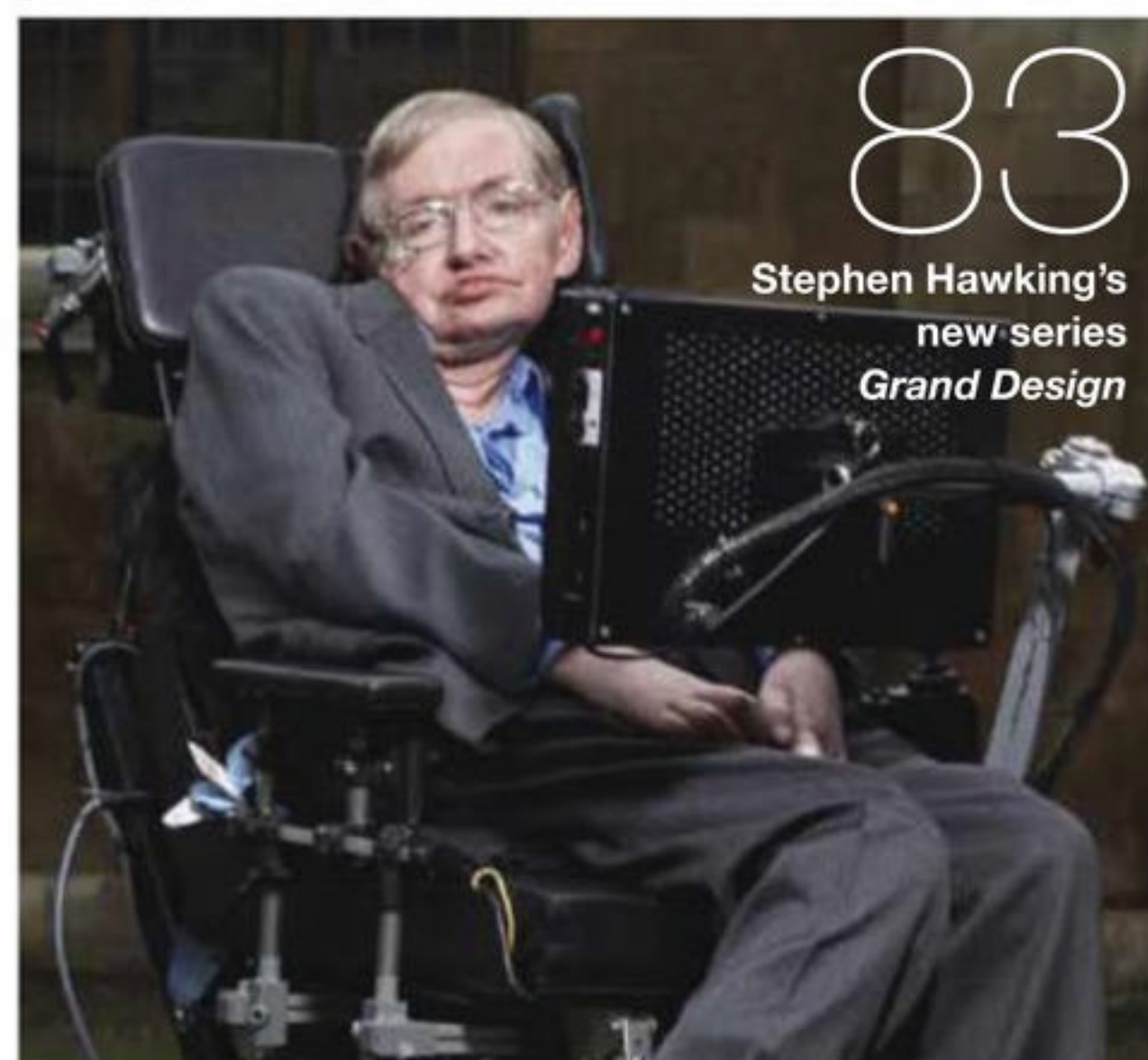
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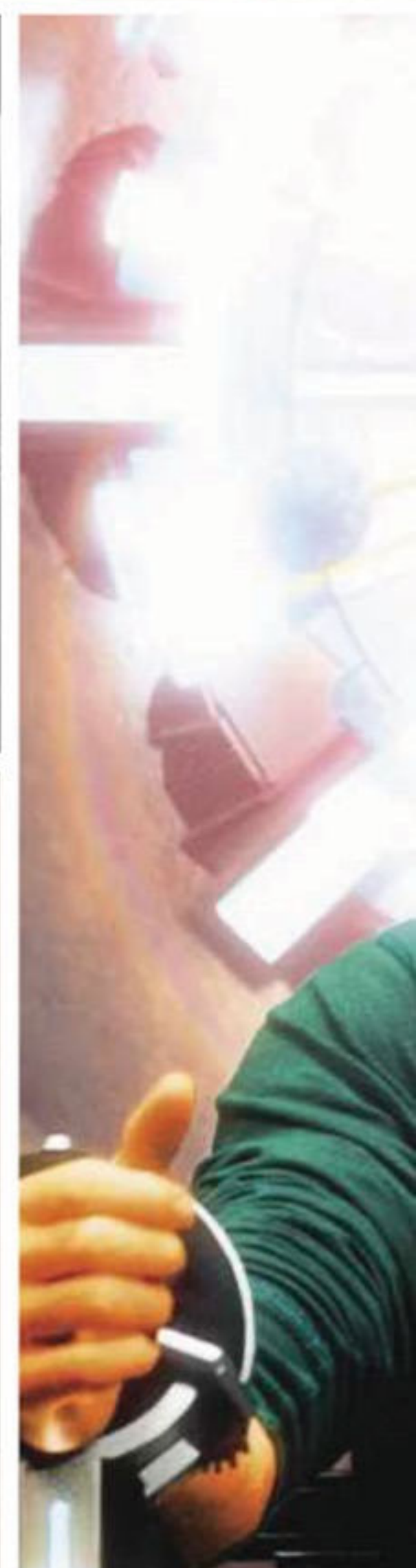
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"That is full mind control, Total Recall-style, plucked from the tree of science-fiction"

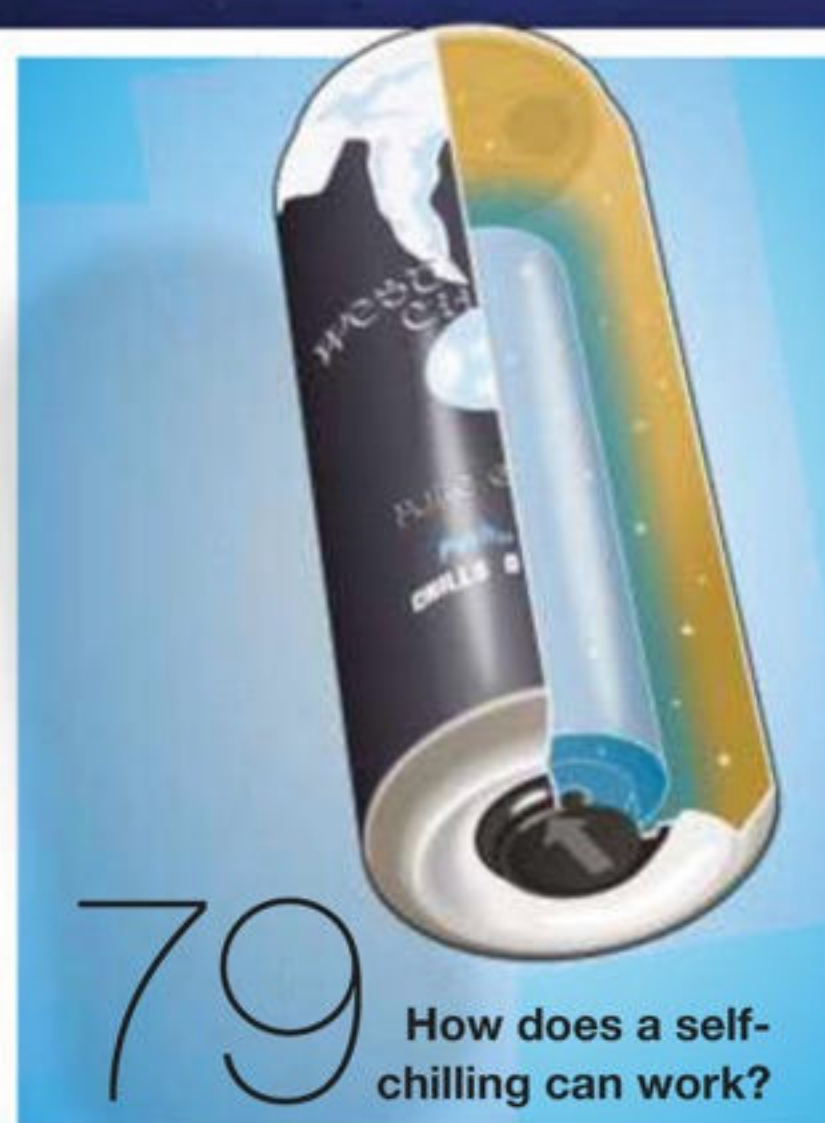
Nobel prize-winning biologist Professor Susumu Tonegawa on efforts to manipulate memory. See *Masters Of Memory*, p54



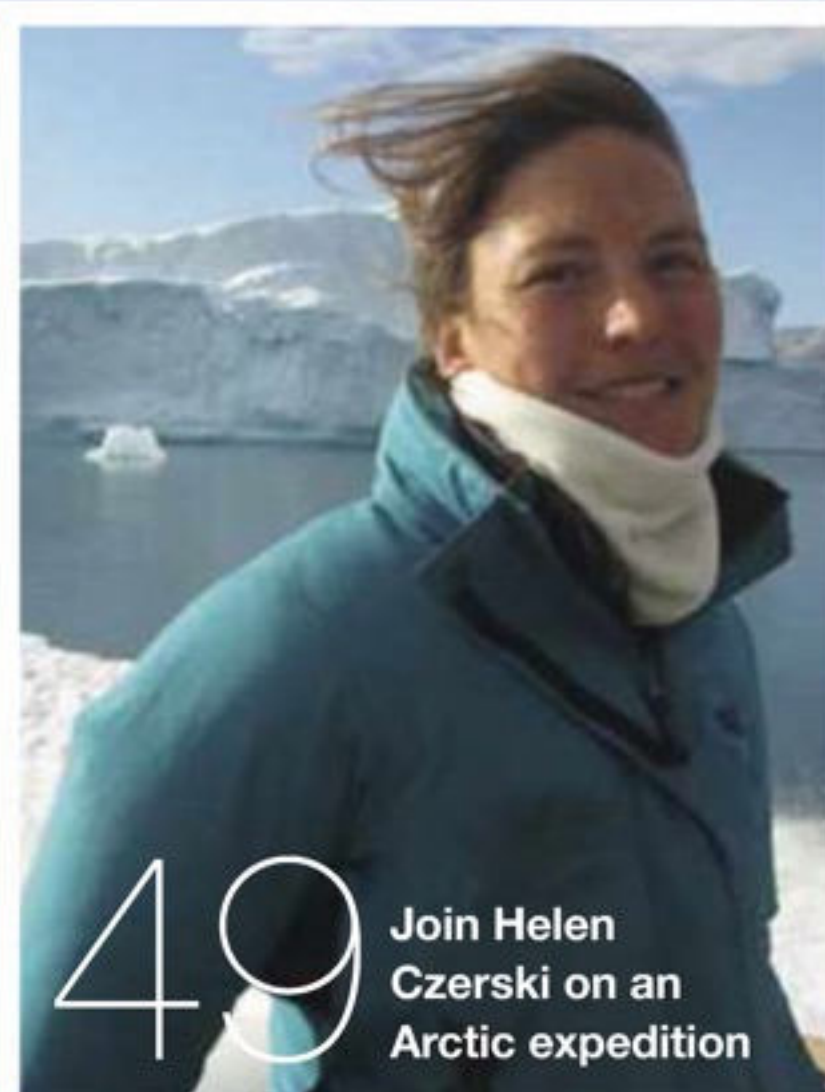
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Anatomy of a drug

This is the most widely-used drug in the world – caffeine. In its pure form, it has long crystals that are naturally white, but have been coloured in this electron microscope view, a winner in this year's Wellcome Image Awards.

Pure caffeine is extremely toxic. The lethal dose is thought to be just 10g, but you would have to drink about 50 double espressos to take in that amount.

The caffeine in your coffee, or tea, is dissolved rather than appearing as crystals. But it takes the form of crystals in pharmaceutical products, such as diet pills. "Caffeine has more than one crystal structure," says Dr Graeme Day, a chemist at the University of Cambridge. "We're currently trying to understand the consequences of the different crystals on caffeine's properties." Pictured here is the crystal that arises at room temperature, known as the beta-polymorph.



Rise and shine

An incredible 3,000 hectares of mirrored troughs make up the Ain Beni Mathar Concentrated Solar Power Plant in Morocco. The curved reflective surfaces focus sunlight onto thin central tubes that run the length of the mirrors. Inside the tubes, molten salt is heated to temperatures of up to 350°C on its way to a steam turbine where it heats the water.

Dust and dirt are constantly cleaned off the mirrors to maintain optimum operating temperatures. At night and on cloudy days, a natural gas plant drives the steam turbine. The combined solar and gas system can provide enough electricity for a million homes a year.

"Relying on its abundance of direct sunlight, Morocco plans to make 50 per cent of its electricity green by 2020," says Tobi Kellner from the UK Centre for Alternative Technology. "Plants like these could form an energy grid across Africa to eventually meet most of its energy needs."



Fanged fish

Identifying eels is easy if you remember the lyrics to that famous Dean Martin song: 'If you stare into its maw and it's got two sets of jaws, that's a moray!' This species, *Enchelycore anatina*, is known as the Fangtooth Moray thanks to its 120 or so needle-like teeth.

These snake-like predators can reach 1.2m long and often hide in holes to ambush their prey – other fish and cephalopods such as squid. First they bite down with their 'oral jaws' – the fangs around the edge of their mouth. Then, just 50 milliseconds later, a second set of 'pharyngeal jaws' bearing 25-50 curved teeth shoot forward, *Alien*-like, from their upper throat. These jaws pull the still-struggling food back into the eel's mouth.

"This pharyngeal transport is a really fascinating innovation," says Dr Rita Mehta of the University of California Santa Cruz, an expert in the biology of long, limbless vertebrates. "Before understanding how moray eels fed, we only knew about a handful of prey-swallowing behaviours."



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At the heart of the image



Need to know

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The mind-controlled robot, p16



Ancient DNA brought back to life

Biologists add 500 million-year-old gene to bacteria to watch evolution in action

Genetic material from bacteria that would have lived 500 million years ago has been resurrected and placed inside modern-day equivalents. Watching how these micro-organisms change over successive generations is allowing researchers to replay evolution in the lab to see whether it takes the same course as it did in nature. The result could give tantalising clues as to whether it was inevitable that the human race would have evolved if history was replayed (see 'Is the human race a fluke?', right).

Rather than plucking the genetic material from an ancient relic, biologists at the Georgia Institute of Technology in the US took what's known about the Elongation Factor-Tu (EF-Tu) gene in modern-day bacteria and worked back to what it would have been like in the microbe's ancestors.

The researchers have been able to recreate the gene as it was 500 million years ago and add it to a harmless version of modern-day *Escherichia coli*, replacing its existing EF-Tu gene. "Our aim was to create a molecular time machine in the lab," says Dr Betül Kacar, who is leading the research. "We went back in time by resurrecting the gene and now we're coming back to the future using evolution. We wanted to know what would happen if we gave this gene a second chance."

Each day, the *E coli* with the ancient gene go through six generations. So within the space of a few months, the biologists are able to see how the organisms have evolved in the small flask that is their home. "The bacteria were sick when we created them," says Kacar. "So they had to evolve and find a way to get healthy."

So far, the EF-Tu gene has not accumulated mutations, which means that it hasn't evolved throughout the 1,000 or so generations of bacteria seen so far. It's the genes around it that have changed. "But this is an ongoing evolutionary process," says Kacar. It remains to be seen whether the EF-Tu gene will start evolving.

As well as studying what happens within these bacteria in the longer term, there are many other avenues for research. "We can add more than one ancient gene, whole networks or maybe even change the whole genome," says Kacar.



Dr Betül Kacar has a front row seat to watch evolution

Is the human race a fluke?



Back to the future: *E. coli* bacteria

If we were able to allow evolution to take its course again on Earth, or 'replay life's tape' as the American evolutionary biologist Stephen Jay Gould once described it, would we get exactly the same clutch of species we see today? Would humans evolve again?

Some biologists believe evolution to be determinate: if life's tape were replayed, we would end up with largely the same species. Others believe the process is not repeatable. "We thought maybe we could replay the tape for one gene and see whether it would adapt in the same way," says Dr Betül Kacar, at Georgia Institute of Technology.

So far the ancient gene has not evolved, which is apparently at odds with what happened in nature. This would indicate that evolution could have taken a different tack in our past and so our presence on Earth was not inevitable.

March of the mind bot

Humanoid robot operated remotely over the internet raises the prospect of brain-controlled avatars

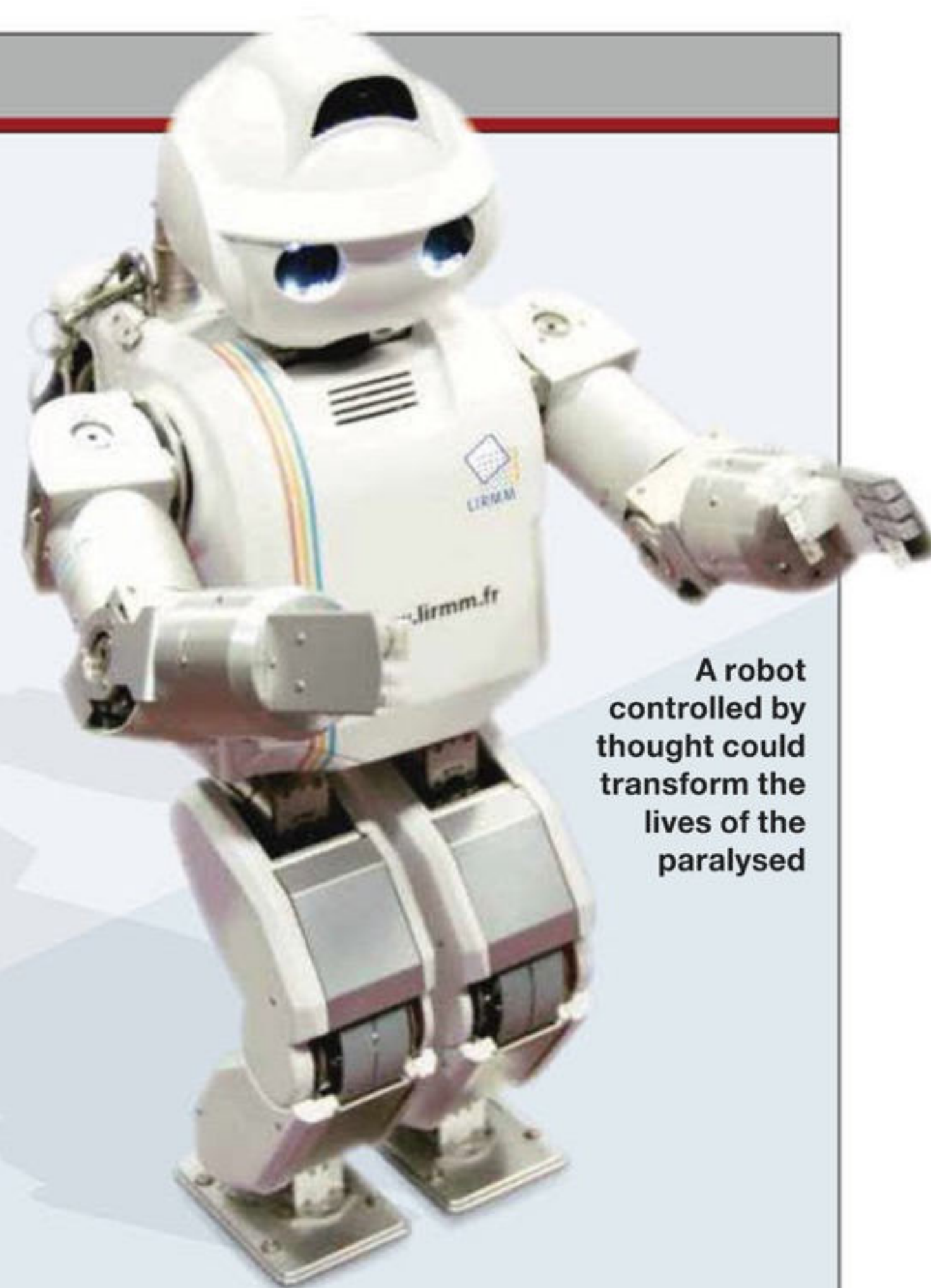
Lying in a brain scanner in France, a university student has controlled a small robot 3,000km away in Israel simply by thinking about moving his own body. While it's not the first instance of a robot being controlled by thought, it is the first time an fMRI scanner has been part of the process.

An fMRI scanner detects changes in brain activity by measuring blood flow in different parts of the brain, potentially giving a greater degree of control over the robot than other methods. In the experiment, carried out by members of the Virtual Embodiment and Robotic Re-embodiment project, a student in the Advanced Virtuality Lab at the Interdisciplinary Center in Israel was trained to produce clear fMRI commands using a virtual avatar. These instructions were then sent over the internet to the Beziers

Technology Institute in France, where they controlled the movements of a 60cm-tall humanoid robot. Imagining moving his left or right hand made the robot move left or right, while imagining moving his legs made it walk forwards.

Back in 2007, a team led by Associate Professor Rajesh Rao at the University of Washington showed that it is possible to control a robot avatar using an EEG cap that measures electrical activity in the brain. It was the first demonstration that a humanoid robot can be controlled remotely by thought. But fMRI "allows more types of brain signals to be distinguished," says Rao, who was not involved in the recent research.

It's hoped that it could be used to assist paralysed people, although the technology is in its infancy. "The fMRI recording



A robot controlled by thought could transform the lives of the paralysed

equipment is currently too expensive and bulky to be of practical use to a paraplegic patient," says Rao.

The researchers plan to develop the system so more instructions can be distinguished. They also hope to feed back sensations to the operator so they feel as though the robot is part of their own body.

Dinosaurs of a feather

Fossil find indicates all dinosaurs may have had some form of plumage

A fossil found in 150-million-year-old rocks in Germany adds weight to the idea that all dinosaurs sported feathers. The fossil, which is incredibly well-preserved, is of a tiny predatory dinosaur, *Sciurumimus albersdoerferi*. It was covered in a hair-like fuzz and had a bushy tail – hence its name, *Sciurumimus*, which means 'squirrel mimic'.

Finding a feathered dinosaur is nothing new – over the past 15 years, 30 types of feathered species have been unearthed. What makes *Sciurumimus* so interesting is that it is an early form of bipedal dinosaur, or theropod, known as a megalosauroid. At just 72cm long, *Sciurumimus* could only have hunted small animals, like fish and lizards.

Dr Oliver Rauhut and colleagues at the Ludwig Maximilians University of Munich used UV light to study the fossil, as this can reveal structures near-invisible to the naked eye, including the hair-like filaments on the creature's tail and body. "The discovery moves the presence of filaments quite a bit down the theropod family tree," says Dr Rauhut. "*Sciurumimus* strengthens the idea that the common ancestor of all dinosaurs had filaments."



The remarkably well preserved fossil of *Sciurumimus albersdoerferi*, which was found in a limestone slab

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New views of Mars

After a nail-biting end to its long journey to the Red Planet, NASA's Curiosity rover sent back first glimpses of its landing site



Above are some of the first images of the Red Planet beamed back to Earth from NASA's Curiosity rover, having made a successful landing on 6 August. As part of the \$2.5 billion Mars Science Laboratory mission, the nuclear-powered vehicle has been lowered into Gale Crater, near the Red Planet's equator. Its aim is to investigate whether the region could ever have been home to life.

As the pictures above show, Curiosity will encounter some rough terrain on its travels. Its main target is Mount Sharp, which rises 5.5km above the crater floor. The mountain is built from ancient sediments, some of which were laid down when Mars still had water on its surface.

Dr John Bridges, a planetary scientist at the University of Leicester, is leading a team of French and British experts in California analysing data from Curiosity. "In the next few weeks, we will be part of the mapping effort, characterising the landing site and working out the science priorities before we head off to Mount Sharp and its clay-rich zone," says Bridges. "In the longer term we'll study the

mineralogy of areas that have experienced the action of water, to work out the temperature, acidity, composition of the fluid and how long water existed on Mars. This will help us understand the ancient environments on Mars where life might have existed."

The largest payload ever delivered to another planet's surface, Curiosity carries a suite of 17 cameras. Perhaps the most intriguing images will come from the rover's ChemCam. Part of this instrument includes the highest resolution camera ever sent to the surface of Mars. ChemCam will be used to look for alterations to rocks caused by the presence of water in the past. It also carries a laser to vaporise rock and soil so their components can be analysed. It will be capable of detecting the chemical ingredients of life – oxygen, nitrogen, carbon and hydrogen – as well as toxic materials that could present a hazard to visiting astronauts in the future.

horizon Watch a Horizon documentary about the Curiosity rover on BBC iPlayer until 17 September. <http://bbc.in/Pf6ou2>

1. Curiosity's destination looms large on the horizon: the slopes of Mount Sharp in the heart of Gale Crater.

2. The rover's Mars Descent Imager captures the heat shield dropping away. The shield protected Curiosity from the searing temperatures endured upon entry into the Martian atmosphere.

3. One of the first images from Curiosity shows its wheel firmly planted on the Martian surface, confirming a safe landing.

4. The first colour image sent back by Curiosity shows the rim of Gale Crater. It's murky because the dust cover picked up particles during the descent; the cover was set to be removed soon after landing.

25

years before the first symptoms show is the point at which early warning signs of Alzheimer's disease can be detected, a new study looking at molecular changes in the brain has found.

14,505

years ago is when a reindeer was carved into the wall of a cave in south Wales, making the picture Britain's oldest known rock art. The carving was dated by scientists from NERC-Open University.

2

millimetres is the reduction in width of hopbush leaves in Australia over the past 127 years – a 40 per cent decrease, which is being put down to global warming.

Mapped onto a visible light image, the presence of dark matter between two galaxy clusters is revealed in blue; yellow contours show its density

Dark matter bares its tendrils

The detection of filaments of the enigmatic substance could help reveal its make-up

Part of an invisible 'skeleton' that appears to shape the Universe has been 'seen' for the first time. Filaments of dark matter have been detected between two galaxies – a discovery that is not only further proof of the mysterious stuff's existence, but that may also help astronomers determine exactly what it is.

According to modern cosmology, dark matter – which neither emits nor absorbs light, and so cannot be seen directly – arranged itself into a network of filaments after the Big Bang. The theory also states that large collections of galaxies, known as galaxy clusters, formed where these filaments intersect. Dark matter's presence is revealed by the way its gravity bends light from distant galaxies, distorting their shapes as seen from Earth. But dark matter filaments contain relatively little mass, making them difficult to detect.

Now an international team of astronomers have got around this problem by using the Subaru telescope in Hawaii to observe the gravitational

lensing produced by a particularly massive filament that sits between two galaxy clusters, Abel 222 and Abel 223. Not only is it massive, it is also orientated so the lensing effect is relatively strong as seen from Earth.

"We look almost exactly along the long axis of the filament, and thus see most of it projected onto a small patch of the sky," says Dr Jörg Dietrich, who was a cosmologist at the University of Michigan at the time he undertook the research.

The team observed tens of thousands of galaxies that sit behind clusters Abel 222 and Abel 223. They found that the observable mass of the clusters, such as the stars, could not account for all the lensing. The rest, they say, is caused by dark matter.

Studying the lensing allowed the filament's location and shape to be determined. Developing the technique further could help to reveal whether dark matter is made up of cold, slow-moving particles or warm, fast-moving ones, as the two would collect differently on the filament.

Moderate alcohol consumption may help to prevent osteoporosis, according to a US study of 40 women. When women who regularly had one or two drinks a day temporarily stopped drinking, the rate at which old bone was removed increased.

Reducing the build-up of RNA in muscles can reverse symptoms of myotonic muscular dystrophy in mice, a study at the University of Rochester Medical Center in the US has found. The find could offer new hope for human sufferers.

People carrying out reconnaissance before committing a terrorist act have been found to secrete a steroid-based chemical that could be used to sniff them out.

GOOD NEWS BAD NEWS

Every degree of global warming brings a 10 per cent increase in lightning activity, say researchers at Tel Aviv University in Israel. This could cause more frequent and intense wildfires. They also predict fewer but more intense rainstorms in some regions, leading to flash flooding.

The first study of the long-term consequences of exposure to lunar dust has concluded that the fine, sharp dust could present a lung cancer risk, and could scratch the cornea in your eyes. Relocating to the Moon may not be such a good idea after all.

Urban sparrow populations may be declining because it's too noisy for mums to hear their chicks, so they are less likely to feed them, a University of Sheffield study has found.

Smart headlights make rain disappear



A new car headlight system aims to eliminate the distraction of falling rain at night – by making it vanish. The US researchers behind the technology accomplish this feat by preventing light from reaching individual drops. The system, developed at Carnegie Mellon University in Pennsylvania, USA, detects raindrops that are less than 3m away,

which are the most distracting. It then predicts their path and blocks the light rays that would illuminate them. “By reducing backscattered light, raindrops disappear,” says Dr Robert Tamburo at Carnegie Mellon.

The prototype system currently takes around 13 milliseconds to process the data and control the headlight. But the

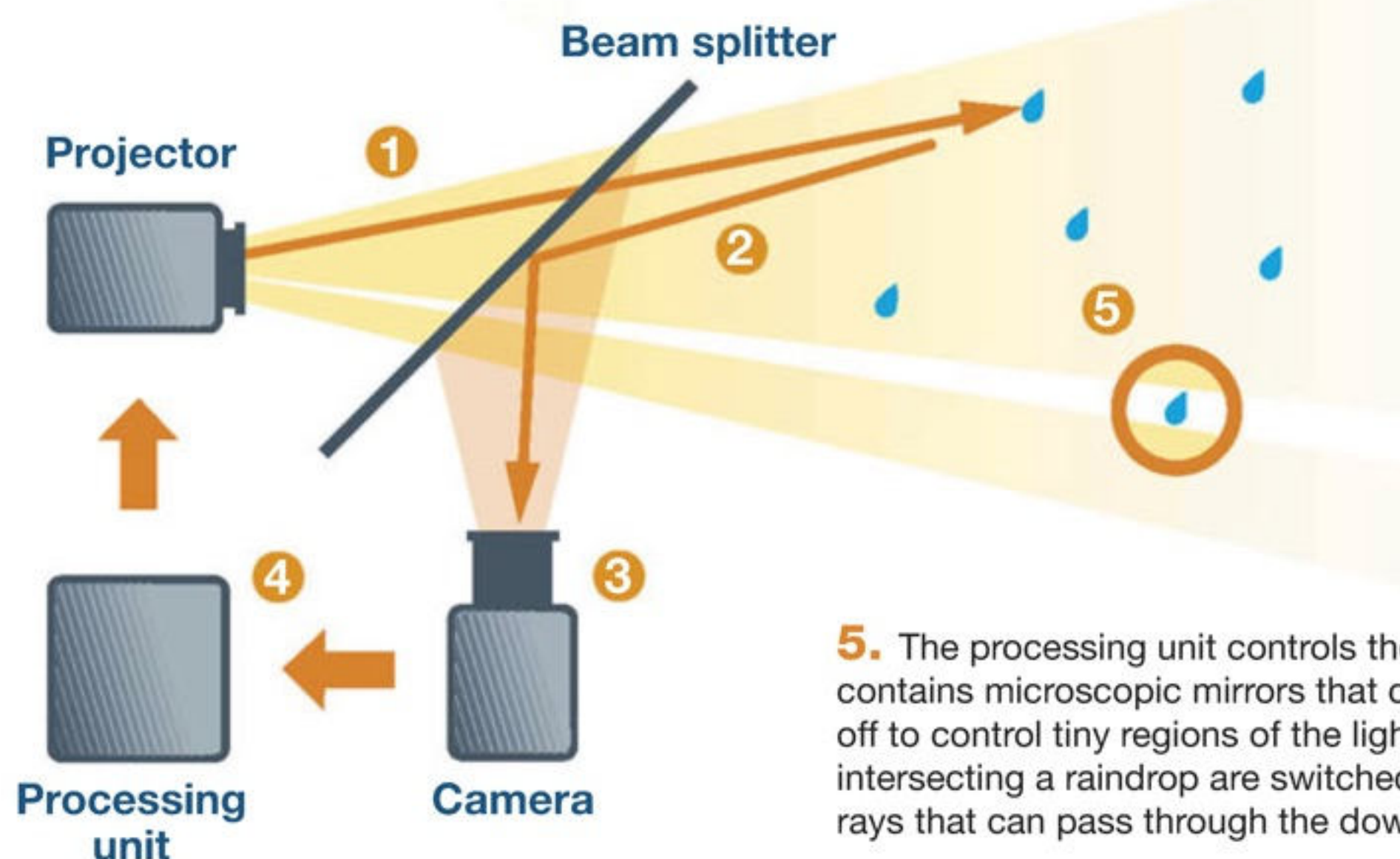
researchers say the system needs to be faster so that it can blot out a high proportion of raindrops when travelling faster than 30km/h (18mph). Currently 30cm³ in size, the developers want to shrink the system to 5 to 15cm³ for it to be used in cars.

The developers say such improvements will take another three to four years.

1. A projector emits light, acting as a headlight.

2. Light reflected from the falling raindrops is directed off a beam splitter to a camera.

3. The camera captures the falling precipitation at the top of the driver's field of view.



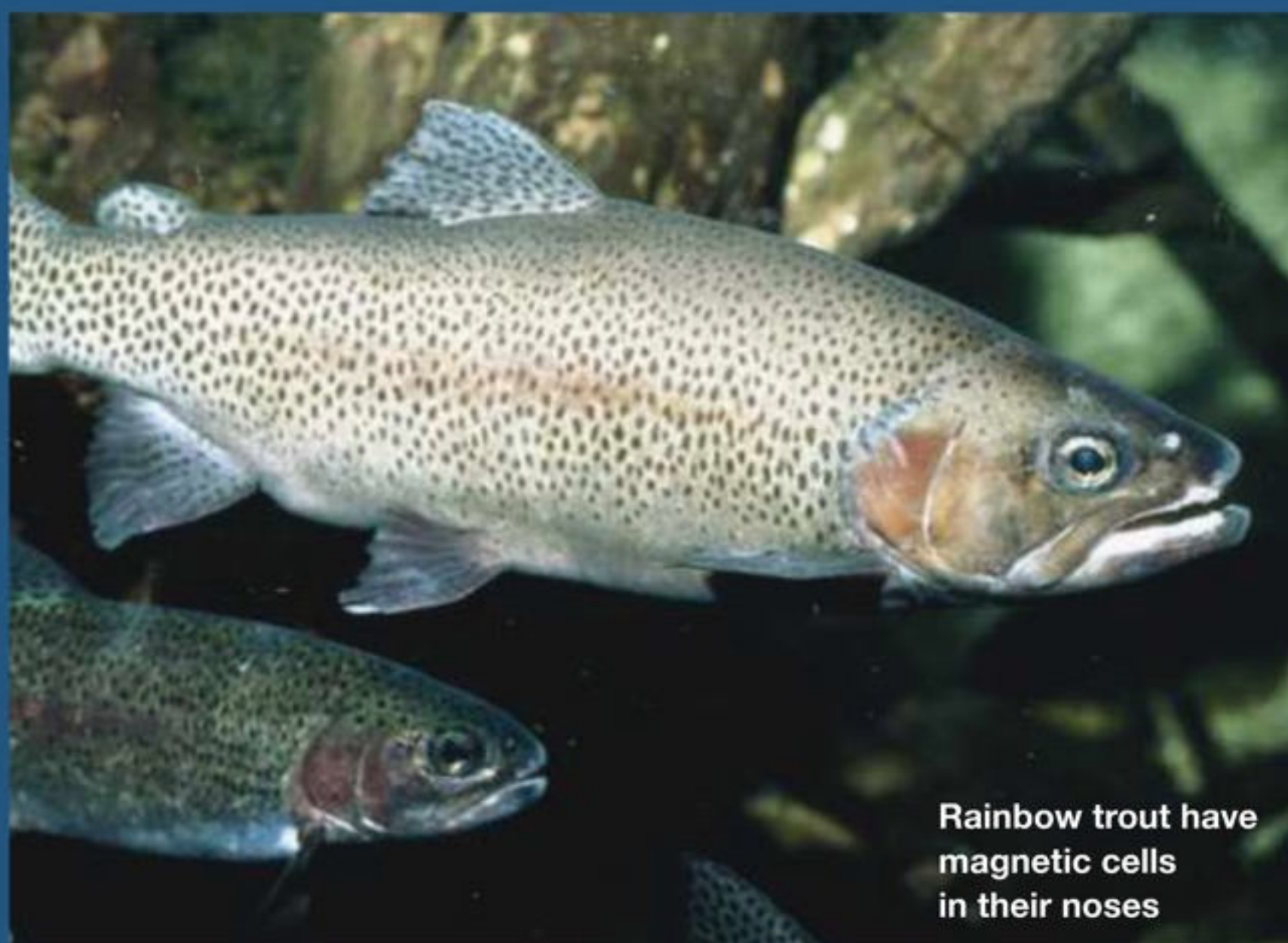
4. A processing unit records the position of each raindrop and uses an algorithm to quickly predict the drops' trajectory.

5. The processing unit controls the projector, which contains microscopic mirrors that can be switched on or off to control tiny regions of the light beam. Any light rays intersecting a raindrop are switched off, leaving only the rays that can pass through the downpour unimpeded.

Weird science

Fish follow their noses

The cells that enable rainbow trout to detect the Earth's magnetic field and use it to navigate back to the site where they hatched have been located by an international team of scientists. The cells are located in the noses of the fish and are the first magnetic field-sensing cells isolated in any animal. It was thought that iron-rich nerve cells in pigeons' beaks also detect Earth's magnetic field. But earlier this year, what were thought to be nerve cells were found to be immune system cells instead.



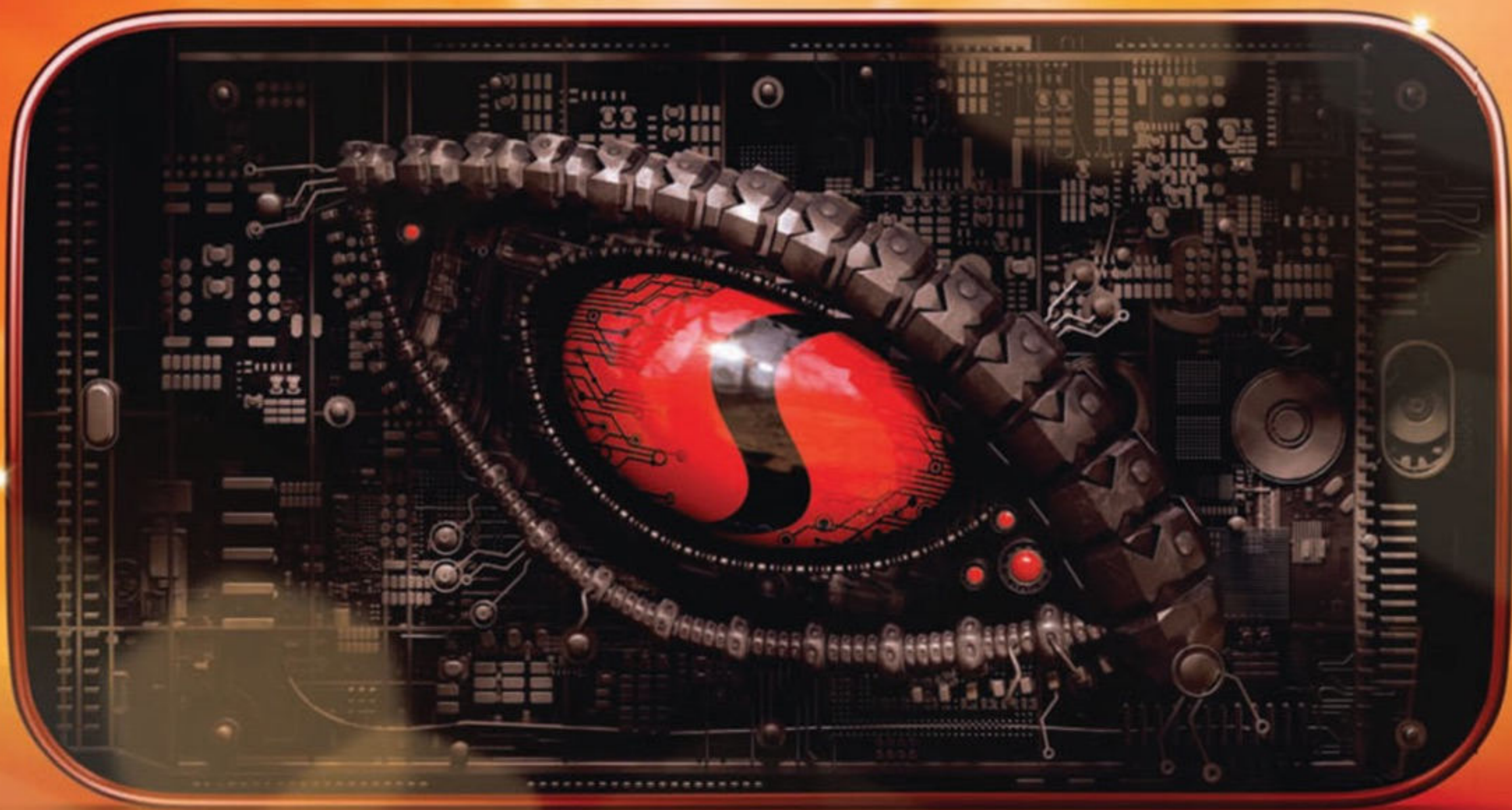
Rainbow trout have magnetic cells in their noses

Graphene's latest miracle

Graphene, the one-atom-thick sheet of carbon with exceptional strength and conductivity, has been found to have another trick – it is self-healing. Physicists in the UK used an electron beam to etch holes into a graphene sheet, adding atoms of palladium and nickel to grow the holes. Remarkably, loose carbon atoms nearby displaced the metal atoms, knitting the sheet back together. This discovery could lead to a new way of building graphene structures, simply by adding carbon atoms along existing sheet edges.



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INSIGHT

T-shirt charger**What's that, and what's it for?**

It's a T-shirt that's been modified so that the fabric can store electrical charge. It offers a convenient way to charge your mobile phone and other gadgets. In the longer term, the same technology will be needed to power gadgets made from flexible electronics, enabling devices like mobile phones that can be rolled up.

How was it made?

Engineers at the University of South Carolina, USA, took a plain cotton T-shirt and soaked it in a sodium fluoride solution. Then they baked it in an oxygen-free environment, which converted the surfaces of the T-shirt's cellulose fibres into an extremely porous form of carbon known as activated carbon. The material remains flexible.

How does it work?

Small parts of the T-shirt were used as electrodes, which showed that the fabric acts as a capacitor, ie it stores electrical charge. This charge could be used to power a device. By adding a thin layer of manganese oxide to the fibres, it then became a super-capacitor with the ability to be charged thousands of times without diminished performance.

Is there a risk of electrocution?

No, a protective layer would mean there is no chance of you experiencing an electric shock from your gadget-friendly garment.

When will they be in the shops?

The engineers hope to be able to commercialise their technology within the next couple of years, working with industrial partners.

Turning T-shirts into batteries



ROUND UP

This month's top science stories from around the globe

ASTRONOMY

Another Pluto moon found

Pluto may no longer be classified as a planet, but it is now known to boast no fewer than five moons. The fifth, discovered using the Hubble Space Telescope, is just 10 to 25km (6-16 miles) across. It is not clear why this icy dwarf planet has so many satellites. The favoured theory is that all five moons were created billions of years ago, during a collision between Pluto and another large object in the Kuiper belt – a region in the outer Solar System containing many small bodies.

GERONTOLOGY

Caring reverses brain ageing

Tricking old bees into doing the work of younger bees can reverse ageing. In a hive, younger bees care for the larvae, while older bees forage for food. These older bees lose body hair and show reduced brain function. However, researchers found that when young bees are removed from a hive, some older foragers will take on their work. Half the bees that returned to caring for the larvae showed an increased ability to learn new things. The levels of two proteins were also elevated.

SPACE EXPLORATION

NASA's new space vehicle

The space capsule that will relaunch NASA's human spaceflight programme is taking shape. Orion is now at the Kennedy Space Center in Florida, where final assembly work will be carried out. Built for NASA by Lockheed Martin, its big moment will come in 2014 when it will be lifted into space aboard a Delta IV Heavy rocket for an uncrewed test flight. The aim will be to see whether Orion's heat shield can survive re-entry into Earth's atmosphere, when it will be travelling at 40,200km/h (25,000mph).

HEALTH

Proteins help cancer beat drugs

Unlike conventional chemotherapy, more recent targeted drug treatments for cancer specifically act on cancer cells only, so have fewer side effects. However, the success of these treatments has been seen to fade over time. Oncologists in the US have found that cancer cells can become resistant to targeted drugs when exposed to proteins produced by the 'stromal tissue' that surrounds tumours. In future, drugs that reduce the stromal tissue's production of such proteins could increase the effectiveness of treatments.

PALAEONTOLOGY

Giant turtle unearthed

A huge fossil turtle is the latest species to join the ranks of super-reptiles that are now known to have lived in ancient Colombia. Named *Puentemys* and hailing from 60 million-year-old sediments of the Paleocene, it would have had a shell 1.5m (5ft) wide. Living in the same region would have been a snake, *Titanoboa*, which was nearly 14m (45ft) long. The turtle find adds further evidence that tropical reptiles rapidly grew in size following the demise of the dinosaurs.

HUMAN BEHAVIOUR

Women suffer at sea

When the Titanic sank in 1912, three times as many women were saved than men. However, new research has found that this is the exception rather than the rule. When Swedish scientists analysed a database of 18 maritime disasters between 1852 and 2011, they found that the survival rate of women was half that of men, and that children were least likely to survive. Women and children may be helped first, but factors such as men's superior strength and swimming ability come into play.



The Orion capsule at the Michoud Assembly Facility in New Orleans on 22 June



**Faces mapped
in 3D can be
compared with
genetic samples**

Over 800 people have had 3D images of their faces compiled in an effort to understand how genes dictate our appearance. Researchers from the universities of Oxford and Surrey have photographed the faces of volunteers across Britain using four cameras and are now creating 3D representations of each face. It will then be possible to take accurate measurements such as the distance between the eyes. This will enable the researchers to compare facial measurements with genetic data to see if any patterns emerge.

The research forms part of the 'People of the British Isles' project, which is also looking at how our genetic make-up varies across the nation.



The giant turtle *Puentemys* existed 60 million years ago. Inset: palaeontologists unearth its 1.5m fossilised shell

GLACIOLOGY

Ice loss caused by giant chasm

A Grand Canyon-like chasm beneath the Antarctic ice sheet is likely to speed up ice loss in the region and accelerate sea level rise. During an expedition in 2009/10, University of Aberdeen geologist Dr Robert Bingham discovered the Ferrigno Rift using radar equipment. It is 1.5km deep, 10km wide and 100km long. A study published in *Nature* states that, among other things, the rift provides a channel for relatively warm ocean water to travel inland and melt the Ferrigno Glacier above it.

COSMOLOGY

Space has strange chemistry

A new form of chemical bond has been discovered that only exists in space, enabling molecules not found on Earth to form. Electrons in chemical bonds are governed by the Pauli exclusion principle, which means the two cannot occupy the same quantum state. Electrons in bonds usually pair up in couples of opposing spin. But in the intense magnetic field of a white dwarf star, both electrons spin in the same direction, with one shifting to a different position known as the anti-bonding orbital. In spite of this the bond still holds, a simulation has shown.



NEWS IN BRIEF

NASA's Spitzer Space Telescope has discovered an exoplanet that is smaller than Earth. UCF-1.01 is 33 lightyears away – close in astronomical terms. While this planet orbiting another star is fairly diminutive, at two-thirds the size of Earth, it's not the smallest world discovered so far. That honour goes to KOI-961.03, a puny 57 per cent the size of Earth.



The banana genome has been sequenced in the hope of finding genes that will help fight off diseases. Almost all bananas exported to the US and Europe are the Cavendish variety, and are threatened by two fungal diseases – Panama disease and black sigatoka. The sequenced banana is a forefather of the Cavendish, a variety called DH Pahang, and is resistant to the strain of Panama disease that threatens its younger cousin.

A hole has been discovered on the surface of Mars, but it is not clear what created it. The hole was spotted on the slopes of the Pavonis Mons volcano in images taken by the HiRISE instrument on the Mars Reconnaissance Orbiter. The cavern behind the hole is thought to be 20m deep and – protected from the harsh conditions on the surface – would be a relatively hospitable environment for life.

Two life-sized lions carved sometime between 1400 and 1200BC in what is now Turkey have presented archaeologists with a mystery. The big cats were created by the Hittites, who had an empire in the region. But there is no evidence of a Hittite settlement near the statues and they are too large to be moved far. It is thought they may have been created as monuments to nearby springs.

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The Analyst **Robert Matthews**

Battery technology needs to catch up with the gadgets it powers

When the iPad and its rivals first came out, I was almost overwhelmed with desire. Not the desire to own one, but the desire to boot them out of the hands of those smug 'early adopters' who seemed determined to show the things off at every opportunity. Pubs, airport lounges, even bus stops... they insisted on using them anywhere, anytime.

But then I realised the significance of this. Racing to meet a deadline, I fired up my old netbook on a train, only to find its battery was flat after about 30 seconds use. Then I found someone had snapped off the power point under my seat. So there I was, staring at 21st century technology rendered useless by its reliance on 19th century technology.

Raising this with my Chief Technology Officer (AKA my teenaged son Theo), I learned that tablets typically have much better battery lives than netbooks. That

makes sense, I thought: netbooks have been around for five years, an eternity in the world of gadgetry, and battery tech must have improved radically over that time. "Not really," said Theo. "The improvement is mainly due to more efficient chips and better design. The battery tech is the same old lithium-ion technology developed back in the 1980s."

I slightly resented the 'old' bit, as the key breakthroughs in Li-ion tech were made at Oxford University while I was a student there. But there's no getting away from it: batteries remain the weakest link in a host of technologies, from smartphones and tablets to electric cars and renewable energy. And the rate of progress is pathetic. Since the mid-1980s, microchips have become 10,000 times more powerful, while battery capacity has increased by barely 10 per cent.

To be fair, doing any better does mean overcoming some tricky problems. So

“
We'll never get the performance we want until we break with today's approach. What we need is something radical
”

far, the story of battery technology has been largely one of cramming as much electrical energy into units as small and light as possible, repeatedly and without letting it leak away. That's a big ask, as lithium shows: it's a wonderfully light metal (so light, indeed, that it floats), but resents being repeatedly crammed with electrical energy. Early pure lithium batteries got a reputation for bursting into flames – forcing chemists to combine the metal with carbon and other elements, compromising performance.

They've been trying to do better ever since, using all kinds of combinations. Earlier this year, scientists at several institutions unveiled results from prototype batteries that combine lithium with various compounds to allow air in the battery to trigger an electric current. Such 'lithium-air' batteries could potentially hold over 10 times more energy than today's Li-ion units, but whether they can be made cheap and safe enough is far from clear.

I can't help feeling we'll never get the performance we want out of today's batteries until we break with today's approach, which hasn't really changed for 200 years. What we need is something radical – like the thermowave idea being explored by Prof Michael Strano and colleagues at the Massachusetts Institute of Technology. This involves using tiny lasers to trigger chemical reactions that propel electrons along carbon nanotubes, producing electrical energy. The team thinks this could transform the energy capacity of batteries – and thus make possible halfway-decent electric cars, among other long-awaited wonders.

For years the frankly pathetic state of battery technology has been masked by the huge improvements in what it powers. It's time some bright spark sorted it out.





The Futurist Stephen Baxter

Computers: teaching us the nature of creativity

Much of what we see in today's movies was generated by a computer. Could a computer write the script, though? Or a novel?

Computers can read, up to a point. By analysing the recurrence of key words, text analysis programs can pick out main headings and key topics from dry factual reports. But if you feed in a novel, as has been tried by Jon Adams at the London School of Economics

using a system called Alceste, the program may pick out themes like the setting, but will struggle to summarise the plot, and will have no idea about the book's deeper themes or emotional content.

There have been experiments in computer-generated prose. A program called MEXICA, reported the *Journal of Cognitive Science* in 2007, takes a basic story outline, assigns numerical values to emotions and tensions between characters, and develops the story from logical extrapolations. It seems plausible that such a program could produce very formulaic fiction, but it's hard to imagine it delivering anything 'literary'. Think of the subtlety found in, for example, one of Terry Pratchett's *Discworld* books, which can parody anything from Shakespeare to the space programme, and which feature a magic-driven computer called Hex with a habit of spitting out bizarre error messages about cucumbers and cheese. Could a machine ever emulate that?

There have been successful experiments in computer creativity in other fields. A system called 'Experiments in Musical Intelligence' (EMI) has

produced new works in the style of Bach, Beethoven and Chopin, by analysing the components of existing music to 'predict' new pieces. Engineers at Sony's Computer Science Laboratory have produced a machine that can create improvised jazz alongside human players. Art-generating software includes The Painting Fool, created by Simon Colton of Imperial College, London. This copies techniques

from the masters, and selects its material from sources like news outlets. Asked to produce something based on Afghanistan, the system came up with an artwork featuring explosions and war graves.

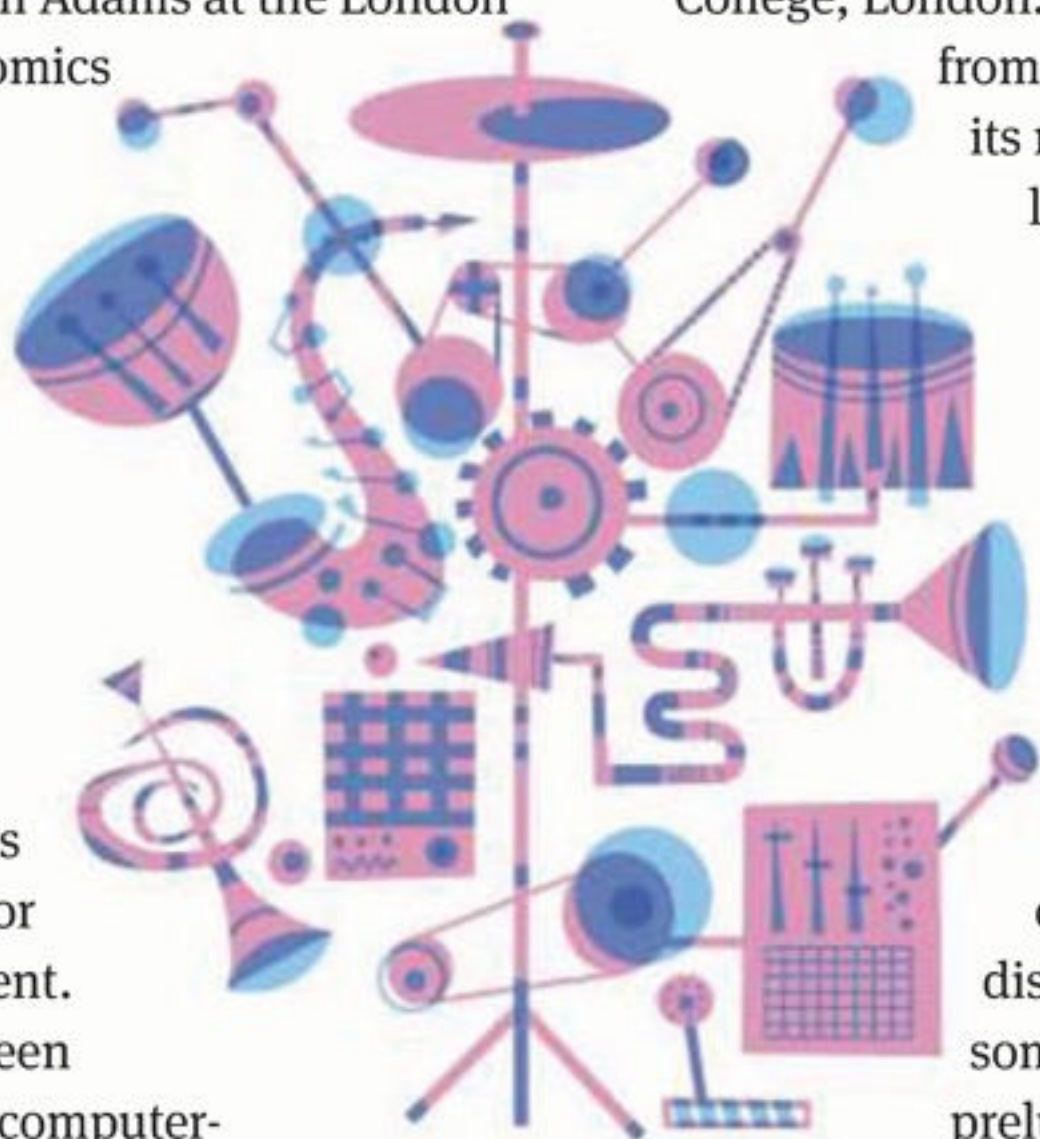
Such experiments teach us something about the nature of creativity. It can be disturbing to find that something as sublime as a prelude apparently by Chopin

was actually generated by a piece of software. EMI's creator, David Cope, has said audiences can be 'delighted, angered, provoked and terrified'. Perhaps to respond to a work of art we need to know there is another human behind it.

And if the finest works of humanity can be emulated by software, perhaps there is less to creativity than we like to believe. Some neuroscientists suspect it is a largely unconscious process, with the brain working like art-generating software to produce images or ideas that the artist 'discovers', rather than creates.

As for computer art, maybe we should just accept it on its own merits. At least you can be sure that no piece of literature as subtle and informed as this column could ever be written by a mere compu%7x5**\$\$\$...

+++Divide By Cucumber Error. Please Reinstall Universe And Reboot +++



MEET THE COLUMNISTS

The Futurist Stephen Baxter

A pre-eminent science-fiction writer and regular *Focus* contributor, his books include *The Science Of Avatar* and the popular *Destiny's Children* series.

The Insider Henry Gee

A senior editor of the respected science journal *Nature*, Henry is the author of several books, including *The Science Of Middle Earth*.

The Eco-sceptic Tom Heap

Tom is an expert on all things green. He presents *Panorama* on BBC One and *Costing The Earth* on Radio 4, which questions accepted truths on green issues.

The Analyst Robert Matthews

After studying physics at Oxford University, Robert became a science writer. He is a visiting reader in science at Aston University.

The Medic Michael Mosley

After training as a doctor, Michael joined the BBC to become a presenter, writer and producer. He's *The One Show's* science man and presented *The Story Of Science*.



The Medic Michael Mosley

A September birthday is the elixir of life

Those with a birthday this month, or in the near future, should take a close look at their pension arrangements.

A recent study of centenarians, published in the *Journal of Ageing Research*, found that those born between September and November (I'll call them the SeptNovs) were far more likely to hit the big 100 than those born at any other time of year.

This follows other studies which show that, at least in England and Wales, SeptNovs are far more likely to become professional footballers or get into a good university. But you can put away the astrology charts: there's a rational explanation for all this.

As far as the centenarians are concerned, the best hypothesis seems to be that infections suffered by the mother during pregnancy (which peak in the winter) may cause long-lasting damage, though there are other possible reasons, such as seasonal hormone changes. If you want a long life the worst months to be born are March (me), May or July.

The academic and athletic reasons why parents should aim for a SeptNov baby are clearer. The school year in England and Wales begins on 1 September, so a child born on or just after that date will be almost a year older than a class-mate born in August. The effects of being bigger and older than your peers are profound and long-lasting: a survey by the Institute of Fiscal Studies, for example, found that children born in August were 20 per cent less likely to get into a top university than those born in September. As for sport, a study of Premiership footballers found that 40 per cent were SeptNovs, with remarkably few born in August.

So if you are a would-be parent hoping to produce a well-educated, long-lived footballer, then you'd do well to hold fire till Christmas...

WHAT DO YOU THINK?

Do 'SeptNov' babies have an advantage over those born in the summer?

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The Music Chain

Much is written about music and the musicians who entertain us, and we rightly exalt great musicians. But there is an interlinked chain of participants, two of which are I believe are crucial to our music scene in today's world. For centuries the music chain was a very short one – composers or songwriters, musicians and listeners, and the judgement on quality was immediate. Recording technologies have changed all this exponentially.

Today, we listen to most of our music from a recording and this gives recording engineers the opportunity to avoid poor acoustics, duff notes and off days. This, of course, means the chain has grown to include the recording engineers, the music distribution system (retailers or downloads), hi-fi manufacturers, hi-fi sellers and the hi-fi purchasers, the latter being the listeners.

I should start by saying that hi-fi has become an adulterated term that no longer has its original meaning because it's applied to much equipment that certainly should not be termed high-fidelity.

It's said that a chain is only as strong as its weakest link. However, I believe there are two particularly strong links that, if removed from the chain, would seriously damage the quality of recorded music. These are the audiophile, or hi-fi connoisseur, and the

specialist hi-fi retailer, the latter in nearly all cases also being the former because it's their interest that has driven them into their particular business. These are the people who most appreciate how exciting and involving music can be and how it can deliver an emotional experience.

Hi-Fi Connoisseurs

So why is the hi-fi connoisseur so important to the music industry? By their nature, audiophiles are generally avid music lovers who enhance their enjoyment through listening to music at its very best quality level, which means playing great recordings through hi-end hi-fi to achieve the most outstanding results. Without the audiophile, the main driver for quality would probably be removed from the chain. Let's be honest, over recent years the majority of music listeners now settle for MP3

convenience and, therefore, mediocre sound quality, that is 'pre-ruined' music. If the pendulum ever swings so far that all but a few listen to highly compressed formats such as MP3, music producers will not waste their resources on producing high quality recordings because it would be commercially unnecessary, even if their recording engineers wanted to achieve the best they could. After all, an MP3 or AAC file, the iTunes default format, downloaded at 128 kbps (the most popular download speed), is about one-eleventh the size of a full resolution CD track, 1411 kbps, so the quality is inevitably far inferior. Information is irretrievably lost and the full dynamic

range is lacking. Using an iPod while jogging does not really raise a quality issue but playing low-resolution tracks through an iPod docking station that feeds into a decent hi-fi system, is a disaster area. It's rubbish quality made louder. Fortunately, there is still significant demand from audiophiles committed to sound quality to sustain the production of high quality recordings, but it would be a tragedy if there weren't. For example, most classical recordings downloaded as an MP3 or AAC file are a complete waste of time because there is so much information missing that they are reduced to just the essence of a tune.

Specialist Hi-Fi Retailers

Just as essential a link in the chain as the hi-fi connoisseur is the specialist hi-fi retailer and the two are rightly dependent on each other. Without the specialist retailer the hi-end hi-fi manufacturer would have to rely on the internet and hi-fi magazine reviewers to try and assess the relative merits and performance of their products against that of their competitors – a notoriously unreliable decision making process. Specialist hi-fi retailers are constantly being offered new products for assessment and potential stocking and, as it is also their hobby as well as their livelihood, they are greatly interested in achieving the best performance and seeking out the most outstanding products and combinations. More than that though is their relationship with audiophiles for, if they are to stay in business, they must satisfy the most discerning customers in the industry. The reality is that audiophiles and specialist hi-fi retailers are essential to each other.



UK Hi-Fi Dealers near you



Future of Recorded Music

What are the future prospects of maintaining high quality music recordings? We must hope that audiophiles, or hi-fi connoisseurs, or perhaps most accurately described, music lovers, will continue to drive the demand for quality. But another important reason for hope within the mass-market is that there is no longer any over-riding reason for MP3 and AAC to have such a following. These formats were designed to overcome very slow download speeds and expensive memory capacity. These are not significant factors for most people now. Full resolution audio streaming, as well as CD quality downloads, are already available and will become the norm as the wider public becomes aware of the tremendous quality benefit. This has happened with HD TV so we know this awareness can grow rapidly. In the meantime, we must highly value hi-fi connoisseurs and specialist hi-fi retailers, of which the ones listed on this page represent the UK's finest. Specialist dealers know how to choose the products that combine as a superb system and how to get the best out of it by expert installation in the home. If there's a price premium over an internet purchase, it's probably a small one, but it's unquestionably worth the difference.



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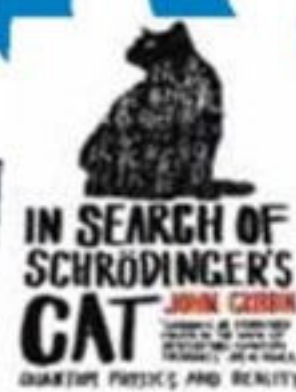
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Your Letters

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Message of the month



The 'Message of the month' writer wins a copy of *In Search Of Schrödinger's Cat* by John Gribbin (Transworld, £9.99)

Thinking machines

In August's Q&A section (p73), Gareth Mitchell professes the belief that no computer, however powerful, will ever demonstrate human-like consciousness. I must disagree with this position. Consciousness is a product of physical processes, and any physical process can be emulated. If we could accurately emulate these physical processes, in silicon or otherwise, consciousness would emerge as the result. To claim otherwise is to imply that there is a metaphysical quality to consciousness, something like the idea of a soul, which is of course an untenable position scientifically.

Robert Somerville

horizon Some scientists believe that an artificial brain would first need to be connected to a body. Baroness Susan Greenfield articulates this view in a clip from BBC Horizon. Watch here: <http://bbc.in/ODgmYd>

Robots may need a body to become self-aware



Self-preservation

Having read and enjoyed the *10 Experiments* article (Summer, p52), I found that most of the exciting experiments were looking to extend (self-medicating implants, DNA editor), preserve (carbon engineering) or make easier the lives of humans (superconductors, fusion). Considering the massive population of the Earth at the moment, will supercharging wheat to feed the starving not just exacerbate overpopulation? What would the effects be of Western and Far Eastern people having even longer lifespans, and more people in third-world countries reaching adulthood and reproducing?

Jim Watson

Carbon conundrum

Today we think and talk in millions, billions and trillions, but do we really know what size those numbers represent? According to the *10 Experiments* article (Summer, p52), just to keep up with the current production of CO₂ we need to remove some 30 billion tonnes of carbon each year from the atmosphere. While digging the footings of the extension to my daughter's house, we were loading 8m³ skips with soil. Each load weighs approximately 8 tonnes. Now I am sure carbon weighs a lot less than soil, but if it weighed the same this would equate to 3,750,000,000 skips full per year, each year, and they intend to either bury this stuff or

use it commercially. The area of the USA is 9,631,418km² – if carbon was as heavy as soil, the entire country would be covered annually to a depth of 3m! The less carbon weighs, the deeper the covering.

Michael D A Rodger, Isle of Man

Multiple universes

Your article on *The Search For Multiple Universes* by Robert Matthews (July, p44) mentions the anthropic principle and the Goldilocks zone. It asks, "Why are conditions in the Cosmos just right for humans?" First, the conditions that are right for all life, not just humans, occur in a thin slice of atmosphere, ocean and land called the biosphere. Second, the article appears to make the assumption

that the fundamental forces, constants and physical parameters can be altered in isolation, and by inference that they remain altered without affecting any of the other forces/parameters, which has not been shown to be possible. If the electromagnetic force were just a few per cent weaker, hydrogen atoms could not exist. However, if it was weaker, other forces/parameters would have a greater effect, which could still produce the conditions suitable to form hydrogen atoms. Victor Stenger deals with this subject



WHAT DO YOU THINK?

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convincingly in his book *The Fallacy Of Fine Tuning*.

Paul Bertenshaw, Ashby de la Zouch

The Search for Multiple Universes article touches at the heart of the imagination and scientific enquiry. I find one excerpt in it, which refers to investigating CMB [Cosmic Microwave Background] radiation as evidence that another Universe has made contact with ours, slightly discombobulating. It reads: "Attempts to find such patterns in existing data have already been made, so far without success." I was under the impression that last year, a team had located possible 'bubble universe' evidence in data from [the space telescope] WMAP and that this would be firmed up with data from the Planck telescope.

Neil C Arvanitis, Reading

Robert Matthews replies: Last year's headlines were sparked by the research we reported, on the discovery of techniques that may one day reveal telltale signs of universes beyond our own. That's not the same as discovering the telltale signs themselves.

I think, therefore I am...

I read Prof Bruce Hood's article but

his reply to a reader's comments (Summer issue, p28) startled me. He states that we are not able to "empty our minds of conscious thoughts"; therefore we are not in control of actions. What hogwash! Of course we are not able to empty our minds of consciousness – if we could we'd be 'unconscious' and unable to turn our conscious minds back on. Surely, this is an adaptation to safeguard the self.

Kathryn O'Neill

I think you'll find...

On page 75 of the August issue you fail to completely explain the redshift in light from distant galaxies. By omission you give the impression, as many explanations do, that there is a visible shift in the colour of light from galaxies receding from our region at near-light speeds. The most distant bodies don't look any redder than they did hundreds of years ago, though all that time they have been accelerating away from us and shifting their light more and more towards the red end of the spectrum. The reason for this is that although the spectrum of light from these fast-receding galaxies has been shifted downwards in frequency, radiation from the

higher parts of their frequency spectrum, like the ultraviolet we can't normally see, has been shifted down into the visible part of the spectrum, filling every part of that spectrum and leaving the source looking unchanged. The way the shift was detected was accidental, in that certain emission absorption lines, from the presence of heavy elements in the receding galaxies, were noted to be appearing on spectrographic analyses at lower points in the spectra than they ought to have.

Roger D Britton

Gareth Mitchell claims that the Suzuki Hayabusa is the world's fastest production motorcycle (August, p78). However, this is a title that is now in dispute since the launch of the 2012 Kawasaki ZZR1400. During a recent speed test, the Kawasaki not only accelerated quicker than the Suzuki, but clocked a top speed of just under 200mph compared to the Suzuki's 188mph. For any manufacturer to claim 'world's fastest' is a non-starter due to a 'gentlemen's agreement' between major manufacturers restricting the maximum speed to 300km/h.

Daz Loczy



The quickest thing on two wheels:
the 2012 Kawasaki ZZR140

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Questions at the frontiers of.. EGYPTOLOGY

Ancient Egypt was one of history's most successful civilisations. **Toby Wilkinson** unearths some of its unsolved mysteries

Q Are there unexplored tombs in the Valley of the Kings?

Since the beginning of modern Egyptology over 200 years ago, the Valley of the Kings has attracted treasure-hunters and archaeologists with the promise of an undisturbed royal tomb from the golden age of the pharaohs.

During the 19th Century, most of the Valley's easily accessible tombs were rediscovered and opened up, but all had been robbed in antiquity. In the early 20th century, systematic excavation revealed further hidden tombs, including intact private burials – but not the hoped-for royal treasure.

In 1912, the American archaeologist Theodore Davis reluctantly concluded that “the Valley of the Tombs is now exhausted”. How wrong he was. Ten years later, and only six feet from where Davis's workmen had halted, Howard Carter discovered the tomb of Tutankhamun. It was the greatest archaeological find of all time.

The discovery stopped excavation work in its tracks. Preoccupied with cataloguing the treasure, Carter was unable to complete the final clearance of the Valley of the Kings down to the bedrock. This left open the possibility that the entrances to one or more tombs remained undiscovered, hidden

beneath the piles of stone chippings and rubble that fill the Valley floor.

Crucially, there is also still one pharaoh for whom no tomb has yet been found, and who may have been buried in the Valley: Tutankhamun's immediate predecessor. Recent excavations in the area left unexplored by Carter have yielded tantalising evidence for ancient tomb-building activity, including workmen's huts and a cache of funeral equipment, but – so far – no royal tomb.

Ultimately, this is a question that time will surely answer. When funding and the political situation in Egypt allow, archaeologists will one day succeed in clearing the Valley of the Kings completely. So if a royal tomb still lies undiscovered, it will be found. It is a slim chance, but an alluring one.

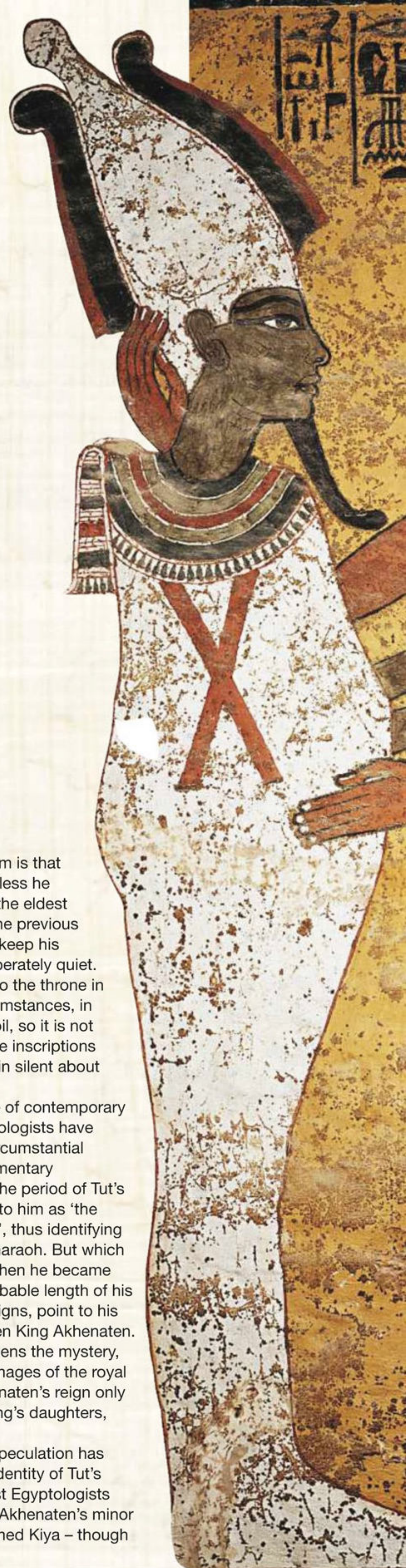
Q Who were Tutankhamun's parents?

Tutankhamun is the most famous Egyptian pharaoh, thanks to the discovery of his tomb with its golden treasure. Yet very little is known about the boy-king himself. Even the most basic details continue to elude us, such as the identity of Tutankhamun's parents. Solving this mystery would shed important new light on a pivotal period of Egyptian history.

A basic problem is that the pharaoh – unless he happened to be the eldest son and heir of the previous king – tended to keep his background deliberately quiet. ‘King Tut’ came to the throne in unorthodox circumstances, in a period of turmoil, so it is not surprising that the inscriptions in his tomb remain silent about his ancestry.

In the absence of contemporary testimony, Egyptologists have fallen back on circumstantial evidence. A fragmentary inscription from the period of Tut's childhood refers to him as ‘the king's bodily son’, thus identifying his father as a pharaoh. But which one? Tut's age when he became king, and the probable length of his predecessors' reigns, point to his father having been King Akhenaten. This merely deepens the mystery, however, since images of the royal family from Akhenaten's reign only ever show the king's daughters, never a son.

Even greater speculation has surrounded the identity of Tut's mother, with most Egyptologists favouring one of Akhenaten's minor wives, a lady named Kiya – though





Detail from the frescoes in Tutankhamun's tomb, showing the king being escorted to the afterlife

without any firm evidence for or against this theory. The development of DNA fingerprinting offered hope of a definitive answer. DNA samples from Tut's mummified body were compared with samples from other royals of the period: Queen Tiye (probably Tut's grandmother), the skeleton thought to be Akhenaten's, and some unidentified mummies from a cache found near the Valley of the Kings.

The results, instead of solving the mystery, have merely raised further questions. Akhenaten does indeed emerge as the most likely candidate for Tut's father. But the boy-king also seems to have been the offspring of an incestuous brother-sister liaison, and Akhenaten is not known to have had a sister. Some Egyptologists have

rejected the DNA study as flawed and have argued for the traditional hypothesis (Akhenaten and Kiya). Others have started scouring the record for a long-lost sister of Akhenaten.

As so often with ancient Egypt, the evidence is partial and contradictory. We may never know the truth about Tutankhamun's origins.

Q Where is the fabled land of Punt?

Ancient Egypt was a prosperous country, and its rulers used their great wealth to acquire precious materials from far and wide. The most famous source of exotic objects was a land called Punt. The Egyptians nicknamed it 'God's Land' for its almost mythical riches, chief among them was incense.

A mission to Punt was a lengthy, expensive and complex undertaking, and was the mark of a powerful ruler. The female pharaoh Hatshepsut, who sent an expedition in the 15th century BC, had the whole episode recorded in lavish detail on the walls of her temple. Scenes show the king and queen of Punt greeting the Egyptian emissaries, a Puntite village with its beehive-shaped huts set among palm trees, and the loading of incense trees onto Egyptian ships for the journey home.

Yet despite such details, one key piece of information is missing – the precise location of Punt. A maritime expedition points to a coastal location, but other ancient Egyptian texts suggest that Punt could also be reached by an overland route. In ancient times, incense trees were particularly abundant in the southwest of the Arabian peninsula, but the flora and fauna depicted in the reliefs of Hatshepsut's temple are more redolent of an African landscape.

Egyptologists have grappled with these contradictory indicators, and have concluded that Punt most likely lay on the Red Sea coast of modern Sudan, in the hinterland of Port Sudan. But this is only a guess. Archaeology is still in its infancy in much of tropical Africa – the economic and political conditions on the ground, the difficult terrain and the poor infrastructure make surveying and excavation extremely difficult.

One day, perhaps, archaeologists digging near the Sudanese coast may stumble across the remains of a lost civilisation, complete with ancient Egyptian pottery and statues. Such a discovery would rewrite the history of Africa. But until then, the kingdom of Punt will remain a mythical land. ■

"Egyptologists have rejected the DNA study as flawed and have argued for the traditional hypothesis"



Dr Toby Wilkinson is an Egyptologist at Cambridge University and the author of *The Rise And Fall Of Ancient Egypt*



THE SECRETS OF HUMAN EVOLUTION

As a BBC Two series examines the remains of three ancient hominins, palaeoanthropologist **Isabelle De Groote** investigates our ancestors' anatomy

Before the first fossils of our ancestors were unearthed, anatomists studied the differences between humans and our closest living relatives, the great apes, for clues as to our origins. Since then, the study of ancient human remains has given us a wealth of information about how humans evolved. As Dr Alice Roberts unearths our distant past on BBC Two's *Prehistoric Autopsy* this autumn, we explore the skeletons of three early human relatives to reconstruct how we conquered the planet.

Until the 1930s, scientists believed that our bigger brain was the key characteristic that drove human evolution over our ape relatives. But over the last few decades, it's become clear that this early theory is wrong. Fossils of hominins (the evolutionary branch that includes humans and our extinct ancestors) are revealing more about the major steps that led to modern humans. The earliest hominin fossils – dating back six million years – show, for instance, that our ancestors walked on two legs long before their brains became bigger.

Certain physical features have made *Homo sapiens* the masters of the planet, enabling us to develop language, use tools and create art. And by examining every aspect of the body, from arms and ankles to feet and teeth, palaeoanthropologists are uncovering the anatomical innovations that have ultimately made us who we are.

Over the page we examine the skeletal remains of the hominin species of *Australopithecus afarensis*, *Homo erectus* and *Homo neanderthalensis*, marking three key areas of human evolution. ►



This autumn on BBC Two, Dr Alice Roberts brings her expertise as an anatomist to *Prehistoric Autopsy*, which examines three prehistoric skeletons.





AUSTRALOPITHECUS AFARENSIS

NICKNAME LUCY'S SPECIES
 EXISTED 3.9 TO 2.9 MILLION YEARS AGO
 HEIGHT 1.5M (MALES), 1M (FEMALES)
 WEIGHT 40KG MALES, 30KG FEMALES

SKULL

The volume of the brain was around 450cm³ – similar to that of apes today. Although a larger brain size was initially thought to have developed first during human evolution, we now know that bipedal walking originated before, and that brains didn't become bigger until our ancestors started eating meat.

ARMS

Australopithecus afarensis had long arms relative to its legs. This feature is more like the body proportions of apes – with their long forearms and short legs – rather than humans, with their short arms and long legs.

HANDS

Curved, elongated fingers indicate *Australopithecus afarensis* had a very strong grip that was probably still grasping branches on trees to feed, build nests and avoid predators. A greater length of the thumb relative to the other fingers is the main similarity with humans.

FEET

Footprints fossilised in volcanic ash dating back 3.6 million years clearly show humans walking on two legs. In contrast, the foot bones of *Australopithecus afarensis* still show a mixture of human and ape characteristics: the big toe is almost in line with the rest of the toes and there's an indication of an arch as in humans. Still, the toes are long and curved for grasping, as in apes.

HIPS

The short and wide, bowl-like shape of the hip bone is typical of a bipedal walker, and it's very different from the high, narrow and forward-facing hip of apes. Its shape helps to support the upper body and reflects the large *gluteus maximus* buttock muscles. The hip of *Australopithecus afarensis* was even wider than that of humans, which may have affected their balance.

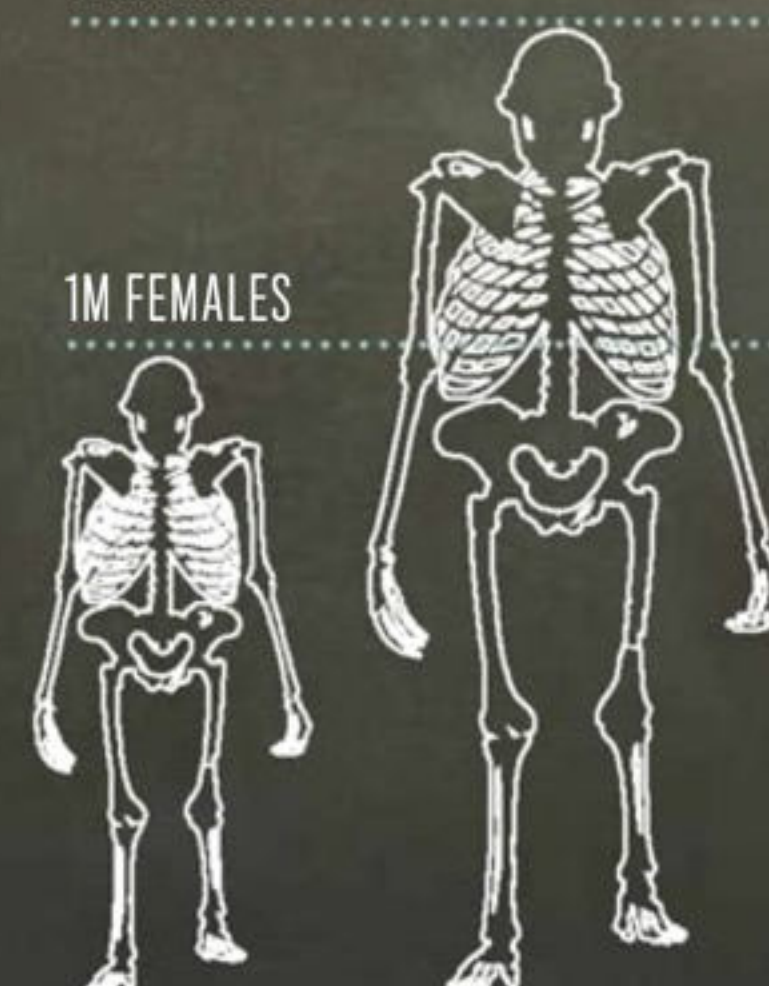
KNEES

The first piece of Lucy that was found was part of her knee joint and it clearly showed that, as in humans, the tops of the legs were far apart due to wide hips. This keeps the centre of gravity in the middle while walking. When walking on two legs, apes stand and walk with their knees apart and will swing from side to side, costing them much more energy.

HEIGHT:

1.5M MALES

1M FEMALES



Over 400 fossils of *Australopithecus afarensis* have been found across East Africa, but one partial skeleton is especially well known. When this female specimen was discovered at Hadar in Ethiopia by palaeoanthropologist Donald Johanson in 1974, his team celebrated by repeatedly playing the Beatles song *Lucy In The Sky With Diamonds*. And so the fossil was named Lucy.

'Lucy's species', *Australopithecus afarensis*, lived from 3.9 to 2.9 million years ago and shared much in common with modern apes. Curved fingers and toes, more mobile shoulders and relatively longer arms indicate that they would have relied on trees to build nests, escape from predators and collect fruit and nuts for food. Their brains were only a third the size of our own and wouldn't have taken as much time to grow. Babies developed as fast as apes do, which would have meant less learning before they reached adulthood, compared to modern humans. The

males were also much larger than females and they probably lived in small family groups.

Despite having ape-like characteristics, *Australopithecus afarensis* is considered an early hominin. This is based on some distinctly human-like evolutionary changes, including smaller canine teeth and a hole in the skull where the spinal cord passes through to the body underneath, which shows that the head was carried above the body and not in front, as in apes.

Most notably, there are several changes to the skeleton for walking on two legs: the hips are wide, short and bowl-shaped to carry the weight of the body, as in humans, while the legs angle inwards to bring the knees and feet together. These adaptations for bipedal walking enabled these early hominins to cover larger distances between food sources – with a range covering East Africa – and allowed our ancestors to survive the changing environment with which they were faced, from rainforests to woodlands.



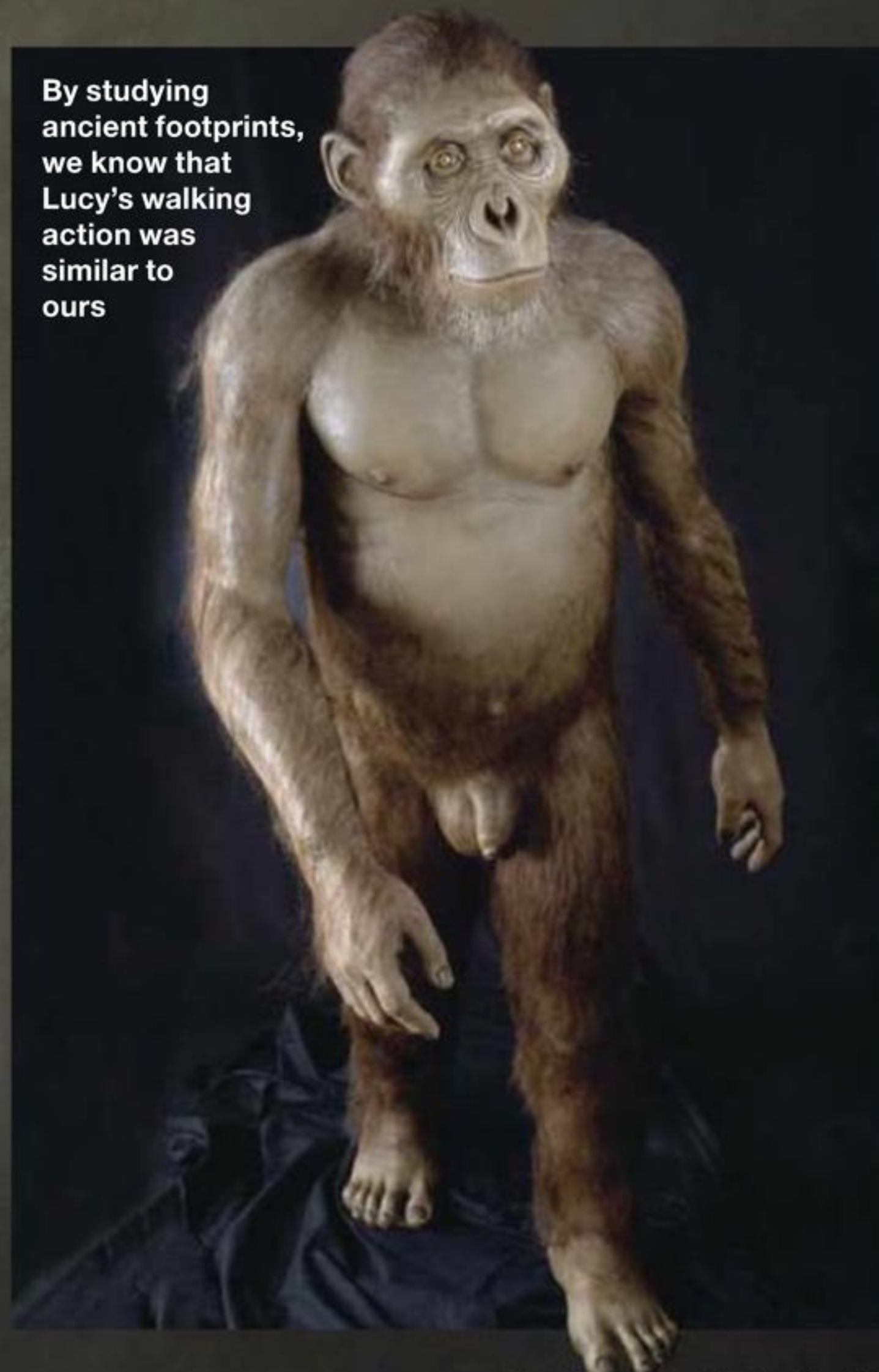
ALICE ROBERTS Behind the scenes on *Prehistoric Autopsy*

"Our closest living relatives – chimpanzees – stand on two legs. The distinction is, are you a *habitual* biped? To get from A to B, is that your locomotion of choice? If it is, that causes changes in your anatomy. Lucy's skeleton had these changes, and it's very similar to our skeletons. Another piece of evidence is the 'Laetoli footprints' from Tanzania. One expert on *Prehistoric Autopsy* is Robin Crompton, who's studied Lucy's gait, primarily by analysing the Laetoli footprints and how they represent stepping onto the ground – compared with humans and chimpanzees. The way we form footprints reflects the pressures applied at different points, because the whole of your foot doesn't hit the floor at the same time: pressure comes through the heel, then down onto the ball and onto the toes. And when Robin looks at Lucy's footprint, it appears quite similar to the way we walk."



Australopithecus afarensis's skull contained a brain similar in size to today's apes

By studying ancient footprints, we know that Lucy's walking action was similar to ours





HOMO ERECTUS

NICKNAME UPRIGHT MAN
 EXISTED 1.9 MILLION TO 200,000 YEARS AGO
 HEIGHT 1.45M TO 1.85M
 WEIGHT 40KG TO 68KG

SKULL

The brain was around 850cm³ in size – between that of humans and apes. It remained this size until *Homo erectus* started hunting animals and eating meat, a food source that yielded enough energy to allow larger brains to evolve.

HANDS

Although there are very few hand fossils for *Homo erectus*, it's believed their hands would have been much like ours. They made stone tools, including the typical tear-shaped hand axes. They would have used these and other tools for hunting and scavenging meat, and to process plants.

LEGS

Homo erectus was the first species with long legs like ours. These would have made bipedal walking much more energy efficient than in early hominins, because longer legs allow a greater distance to be covered with fewer strides.

TEETH

Like counting growth rings in a tree trunk, scientists can calculate a person's age by looking at their perikymata – microscopic growth lines on the surface of tooth enamel. Counting perikymata on the teeth of Turkana Boy, the most complete *Homo erectus* specimen, show he was only nine years old when he died. His body was almost fully-grown, however, which indicates that *Homo erectus* reached adulthood faster than humans do.

ARMS

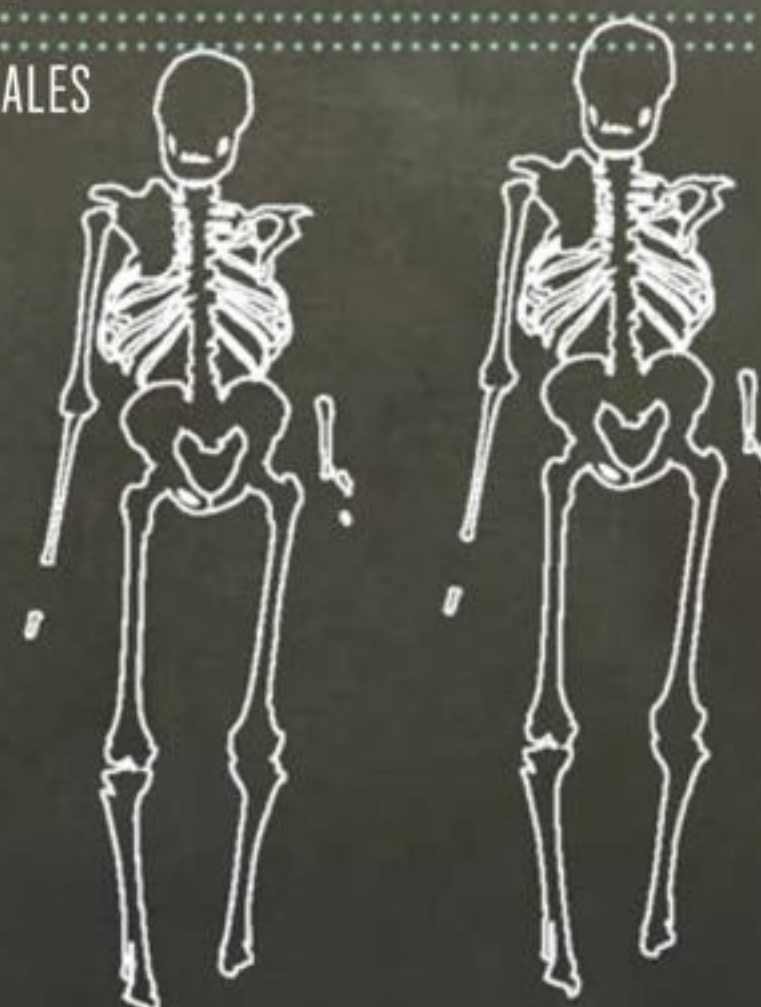
Turkana Boy's skeleton demonstrates that, by 1.5 million years ago, our ancestors had human-like body proportions with long legs and short arms. This indicates that *Homo erectus* no longer relied on the trees, but lived permanently on the ground.



HEIGHT:

1.5M MALES

1.45M FEMALES



During human evolution, various hominin species arose but soon went extinct. *Homo erectus* was one of the exceptions: a long-lived and very successful species that walked the Earth 1.9 million to 200,000 years ago.

The most famous specimen is known as 'Turkana Boy', who was discovered in 1984 by fossil hunter Kamoya Kimeu at Nariokotome, Kenya. This almost complete skeleton provided the first definitive proof that the post-cranial skeleton – everything below the skull – was essentially human over a million years before the brain reached human size. Unlike apes, they stood up straight, hence their nickname: 'upright man'.

Their anatomy, along with tools found with fossils, show that *Homo erectus* was the first true hunter-gatherer. The body is adapted to long-distance walking and running. Biologist Dennis Bramble and anthropologist Dan Lieberman suggest these adaptations enabled them to hunt large mammals.

Without projectile weapons such as bows and arrows, *Homo erectus* may have been a persistence hunter that chased and tracked large animals to exhaustion, then killed them with fairly simple tools. Hunting would have provided meat, a high-energy food necessary to fuel bigger brains.

Although *Homo erectus* still grew up faster than humans today and therefore learned less before they reached maturity, they became a very successful species because they lived in family groups, co-operated, and may even have had a rudimentary form of language, allowing them to communicate. There's also fossil evidence that they cared for the old and weak.

All their abilities – being able to hunt, gather and use tools and fire – made it possible to survive in a range of environments. This enabled *Homo erectus* to not only spread across the whole of Africa, but to become the first human ancestor known to leave the continent and populate western and eastern Asia, all the way to Indonesia.



ALICE ROBERTS
Behind the scenes on
Prehistoric Autopsy

"There was a drying-out on the east side of Africa throughout the Pleistocene, so by 1.5 million years ago there was a significant expansion of grasslands. *Homo erectus* seems to have exploited this new environment. One suggestion is that when they walked out onto the savannah, they would've needed to lose heat. We're relatively hairless compared with chimpanzees, and sweating is an effective way of cooling down because there's no hair to trap the sweat and stop it from evaporating. It's impossible to precisely say when we lost our fur, but this might have been the point in time. We did an interesting experiment on *Prehistoric Autopsy*: we heated somebody who's half-naked and somebody wearing fur, then measured their temperatures to see how well they coped with heat loss. It was a fun way of looking at human physiology and what would've been useful to our ancestors."



This *Homo erectus* skull was found at Sangiran on Java, Indonesia, showing how this species spread across the globe



Homo erectus was able to run, enabling it to hunt large mammals



HOMO NEANDERTHALENSIS

NICKNAME NEANDERTHALS
 EXISTED 200,000 TO 30,000 YEARS AGO
 HEIGHT 1.55M TO 1.7M
 WEIGHT 40KG TO 90KG

SKULL

Neanderthal brains were as large as – and sometimes larger – than that of modern humans. Their skulls still looked primitive, with heavy brow ridges and no chins. They had large noses to heat up the cool, dry air of Ice Age Europe.

CHEST

The chest of the Neanderthal was wider and more funnel-shaped than that of modern humans. Their bodies were shorter and stockier than ours. Today, humans living in cold climates have a similarly stocky build to preserve heat, but in Neanderthals this adaptation was even more pronounced because the Ice ages were so cold – and they didn't have houses or tailored clothing.

ANKLES

Features in the ankles of Neanderthals show that they couldn't run as well as modern humans over long distances. Instead, their feet may have been better adapted to hunt with ambush strategies and sprinting, so they therefore didn't require a long-distance running ability.

ARMS

Neanderthal arms and hands were very strong. The shoulder and arms were adapted to spear thrusting. There's clear evidence that Neanderthals hunted big game, and that they frequently suffered hunting accidents too.

LEGS

The lower parts of Neanderthal legs were shorter than that of humans, with large knees and curved thighbones reflecting their active hunter-gatherer lifestyle. They would often have carried heavy objects over long distances.

HEIGHT:

1.7M MALES

1.55M FEMALES



Although fossils of *Homo neanderthalensis* were first discovered in Belgium in 1829, they weren't recognised as an early human ancestor until a partial skeleton was found in Neanderthal, Germany, in 1856. Hundreds of fossils have since been found, making them our best understood relatives.

Neanderthals lived in the cold climate of Europe and Asia around 200,000 to 30,000 years ago, and they were well adapted to life in their harsh environment: short, stocky bodies and short limbs helped to retain heat in the core while also reducing surface area where heat could be lost. Their noses were huge and probably served to heat and humidify the cold, dry air before it passed down to the lungs.

It's possible Neanderthals were as intelligent as early *Homo sapiens* because their brains were as large, and sometimes larger, than ours. But their skulls still had a primitive large brow ridge and were elongated and flattened in shape.

The way of life for Neanderthals was very similar to that of early modern humans: they lived in caves and rock shelters, and probably wore clothing. Neanderthals were also skilled at making and using tools to hunt large animals like mammoths, and they gathered fruit, legumes and nuts. In terms of culture, they almost certainly used language and even buried their dead – a sophisticated symbolic behaviour not seen in other extinct hominins.

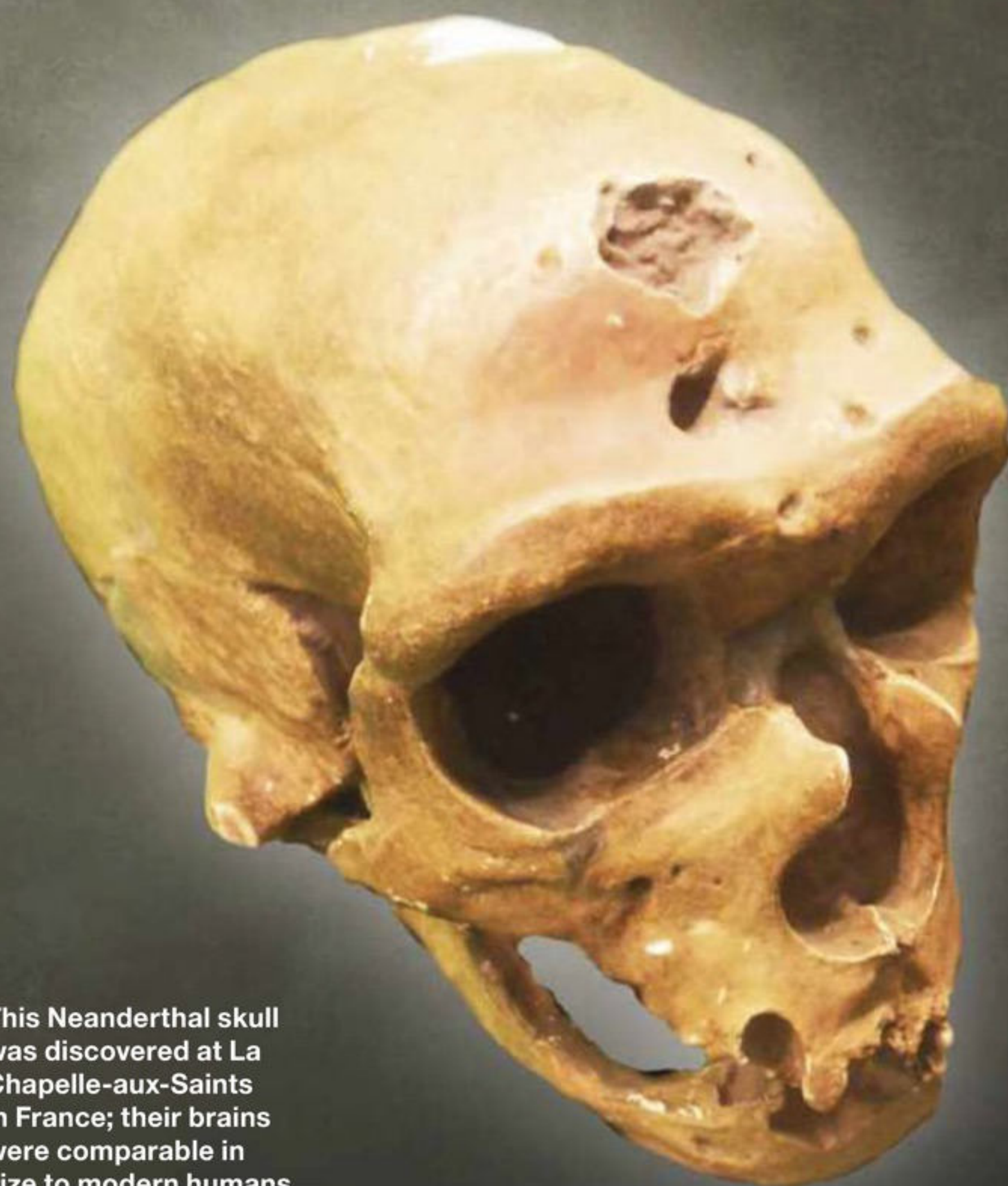
Comparing Neanderthal DNA to that from modern humans has provided fascinating insights. For example, it's clear that when humans left Africa and reached Western Asia, they met and interbred with Neanderthals – people of non-African heritage carry up to three per cent Neanderthal DNA.

Although Neanderthals thrived in Ice Age Europe, they were probably out-competed by the newly-arriving modern humans, and went extinct within about 10,000 years of humans arriving in Europe.



ALICE ROBERTS
Behind the scenes on
Prehistoric Autopsy

"Could Neanderthals throw? There are clues in their anatomy. Archaeologist Dr Colin Shaw has looked at modern humans who regularly throw things and compared the shape of their bones to Neanderthal bones. Colin came into our studio and showed us how he reconstructed the cross-sectional shape of the Neanderthal humerus, the upper arm bone, and what that meant in terms of whether they could throw. We tend to think of our bones as being almost dead because we see skeletons preserved in the ground, but it's a living tissue. If you break a bone, it will repair itself. It's an amazing tissue – obviously it's my favourite! Bones are plastic – they respond to their mechanical environment – so the shape tells you something about how a person used their arms during life. If you looked at the tennis player Andy Murray's arms, his humerus would probably be larger on the racket-playing side."



This Neanderthal skull was discovered at La Chapelle-aux-Saints in France; their brains were comparable in size to modern humans



Neanderthals were adapted to survive the extreme cold of the Ice Age

Dr Isabelle De Groote is a palaeoanthropologist at the Natural History Museum and was a consultant on the BBC series Prehistoric Autopsy

FIND OUT MORE



Prehistoric Autopsy airs on BBC Two this autumn and is presented by Professor Alice Roberts and Dr George McGavin



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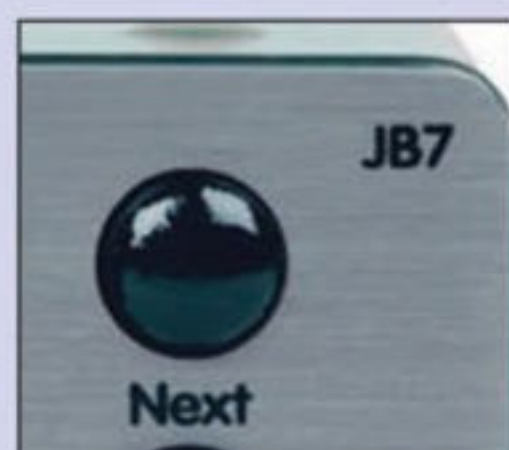
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The face behind the Brennan JB7 range.

Martin Brennan, who designed the JB7, has worked with Sir Clive Sinclair and Sir Alan Sugar and has designed over 20 silicon chips in his career. He was a real pioneer in the computer games industry - he played a central role in the design of the worlds first 64 bit games computer.

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A word about copyright "In 2006 the record companies said unequivocally that they are happy for you to load your own CDs onto a hard disk but the Advertising Standards Authority have asked us to tell you that it is unlawful to copy material without the permission of the copyright holder."

Lords of LIGHTNING

Firing hot plasma is all in a day's work for researchers in Cardiff. **Matthew Chalmers** watches powerful bolts of lightning being generated to protect the aircraft of the future



You're hurtling through the atmosphere in a giant tin can thousands of metres above the ground, looking forward to a gin and tonic. 'BANG!'. Suddenly there's a white flash outside the window. For an instant the cabin falls silent, then there are gasps and puzzled expressions from fellow passengers. Your plane has been struck by a bolt of lightning.

But what if the aircraft was made of materials that aren't quite so good at conducting electricity? That's very likely to be the case in future, when planes are no longer made of aluminium. At a unique facility on a quiet industrial estate on the outskirts of Cardiff, a team of scientists is generating its own bolts of lightning to see how composite

aircraft parts react. "What we're studying here is materials for planes that will fly in 10-20 years from now," explains Professor Manu Haddad who is in charge of the Morgan-Botti Lightning Laboratory, a facility run by Cardiff University and aerospace giant EADS, which includes Airbus as one of its companies.

The scientists at the lightning lab aren't messing around with feeble jolts. Samples can be walloped with currents as high as 100,000 Amps – well in excess of most lightning strikes – while thermal and high-speed cameras and electrical diagnostics record what happens. "The research will lead to better understanding of the conduction mechanisms that may lead to the degradation ►

10²⁰ELECTRONS ARE
TRANSFERRED
FROM A
CLOUD TO
THE GROUND
IN A TYPICAL
LIGHTNING
BOLT

► or failure of carbon-composite materials,” says Haddad.

Commercial aircraft are struck by lightning at least once a year on average and in most cases, the strike doesn't even result in so much as a spilled drink.

That's because the enormous electric current of a lightning bolt, some 30,000 Amps, instantly spreads out across the surface of the plane and continues on its journey to the ground. Safely tucked inside the conducting metal shell of the fuselage, you suffer little more than an adrenaline rush. The aircraft has acted as a protective 'Faraday cage', just as your car would on the ground.

MATERIAL MATTERS

But now that aircraft manufacturers are increasingly turning to advanced materials that are stronger and lighter than traditional aluminium, dealing with a lightning strike becomes a problem. Planes made from carbon composites – multiple layers of carbon fibres embedded in a polymer – can be 20 per cent more fuel-efficient, as well as being able to carry heavier loads. The horizontal tailplane of the Airbus A380 is made almost entirely of carbon-fibre reinforced plastics, while the Airbus A350 and Boeing 787 Dreamliner employ higher percentages of carbon-composite materials. Alas, these new materials are no match for good old aluminium when it comes to conducting electricity.

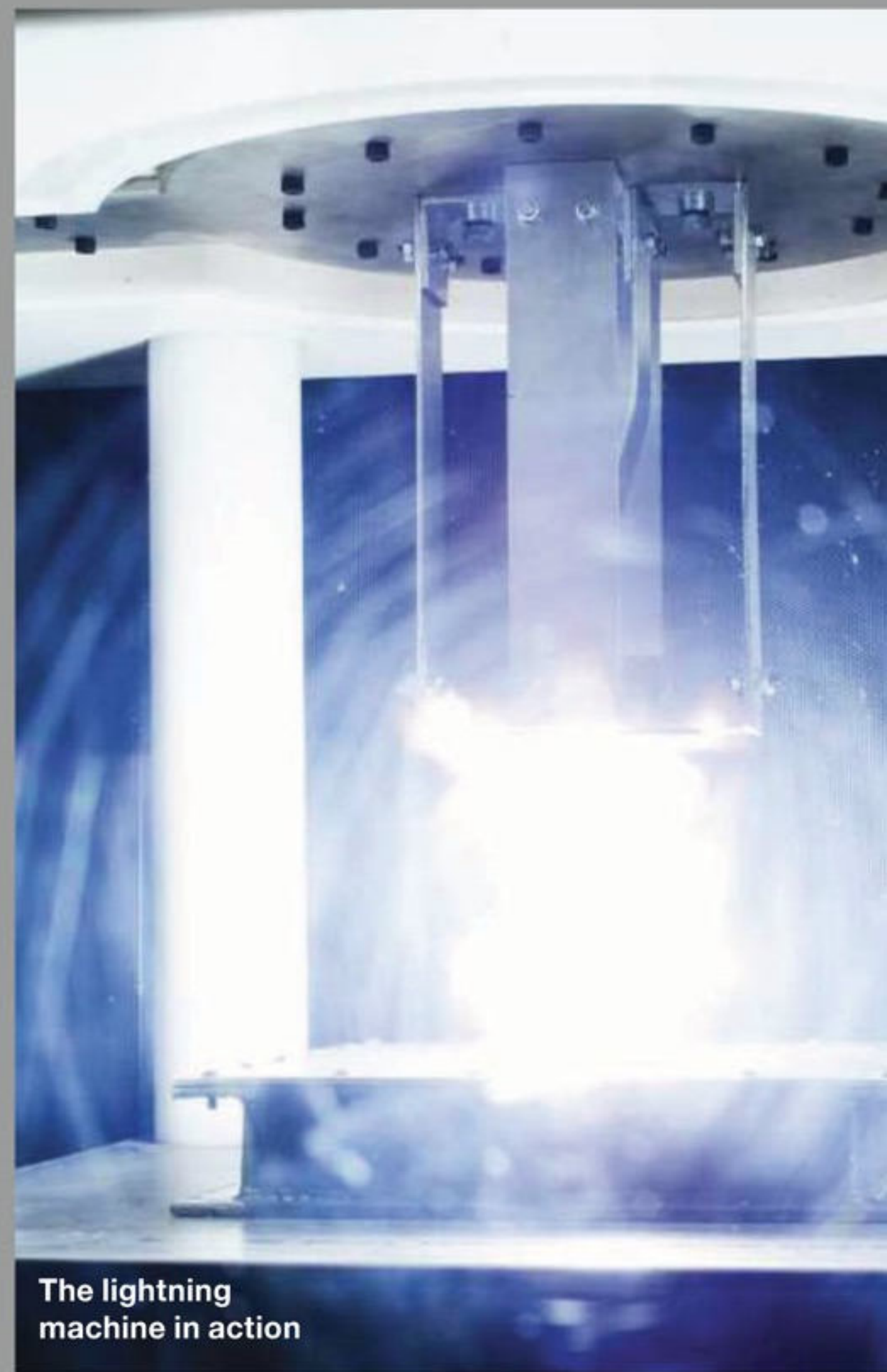
Existing carbon-composite materials in planes have passed strict safety requirements and are covered with a fine metallic mesh that allows a current to dissipate more easily across the surface. But since such lightning protection systems add mass to the aircraft, manufacturers are keen to develop advanced

HOW TO MAKE LIGHTNING

Inside the lightning-making machine at the Morgan-Botti Lightning Laboratory

Lightning forms when warm air rises and friction releases electrons from atoms, causing pockets of charge to build up within clouds. When the charge is large enough, it generates high electrical forces that strip electrons from nearby atoms – a process called ionisation. This carves a channel of separated positive and negative charge moving in the direction of the ground. It's through this narrow channel that the charge that's built up in the cloud can zip to the ground, generating a flash of lightning. At the Morgan-Botti Lightning Laboratory in Cardiff, rather than the current simply leaping through the air, it is directed along a fine tungsten wire. This makes it easier to direct the energy onto the surface of a carbon composite test sample.

The 'lightning machine' – located inside the lab's sample chamber – can be configured as shown on the right, allowing sensors to measure the response of the carbon composite to the artificial lightning. Or, with a slightly different configuration, a cloak can be used to block out light from the lightning flash. This allows high-speed cameras to record sparks coming from the sample material as it is zapped by lightning.



The lightning machine in action

composites with better intrinsic electrical properties.

Back in the lightning lab, a row of carbon composite test panels on display is testament to what a 100,000 Amp jolt can do: it tears open the surface, leaving it looking as though somebody has ripped the fibrous stuffing from a soft toy. The different layers of carbon composite are stuck together using epoxy resins, which do not conduct electricity well. This means that only the top layer of composite conducts the electricity, reducing the material's ability to dissipate the current.

There's another problem too. Individually, the hair-like carbon fibres that run through each layer of composite are good electrical conductors. But in order to maximise the mechanical strength of a component, the fibres in different layers run in different directions. This means that even if a current does pass between layers, it is not as easily conducted as it is in metal. All this

Project manager Chris Stone prepares a carbon-composite test panel for a shock

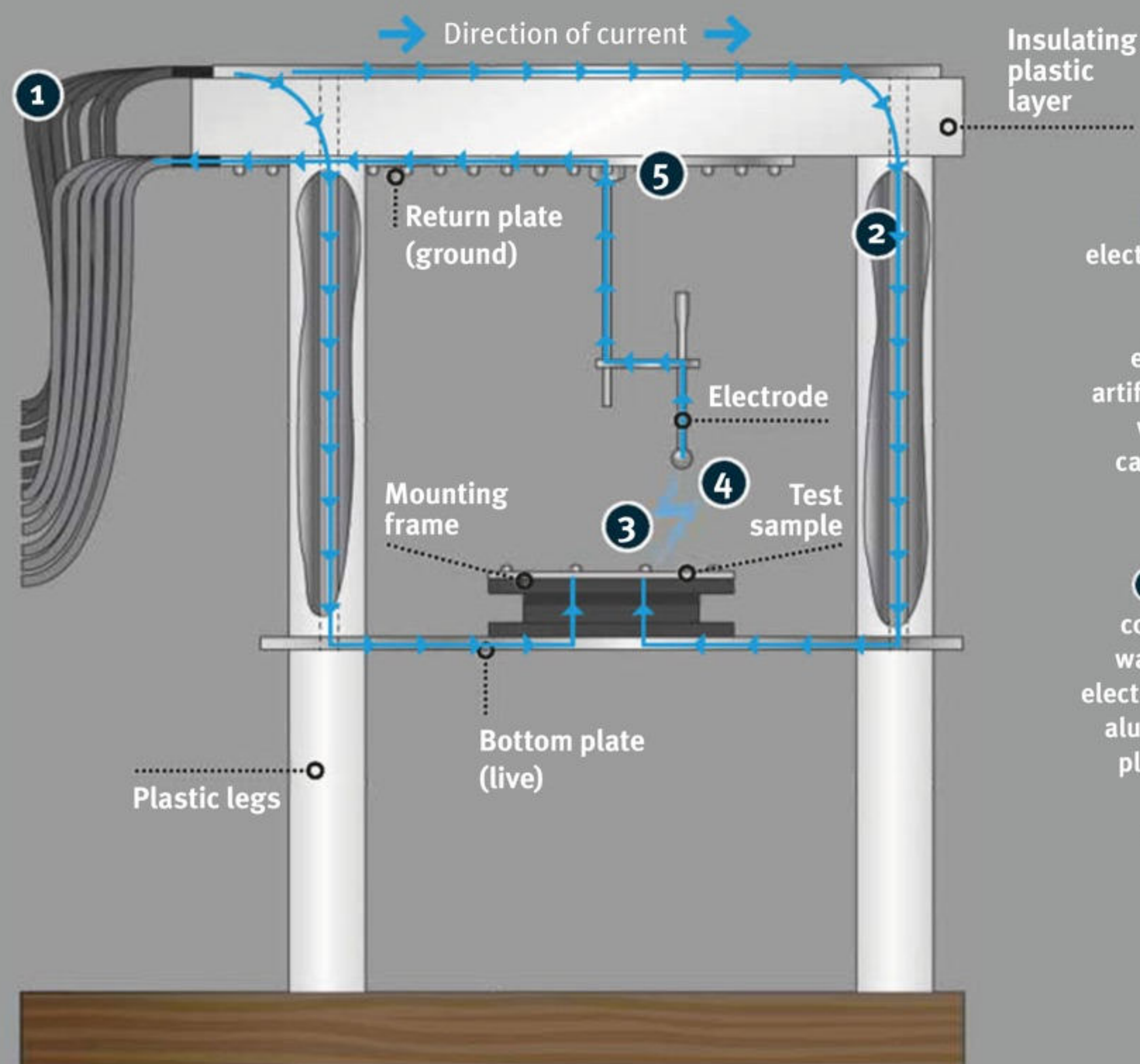




① Six cables carry up to 100,000 Amps of current, generated by a bank of capacitors, to the aluminium top plate.

② The current passes down aluminium conductors within the four plastic legs, before travelling through the bottom plate and into the steel mounting frame.

③ A fine tungsten wire is vaporised by the heat generated by the huge current. Molecules in the surrounding air are also 'dissociated', or broken apart.



④ The flow of electricity between the mounting frame and an electrode is the artificial lightning, which zaps the carbon-fibre test sample.

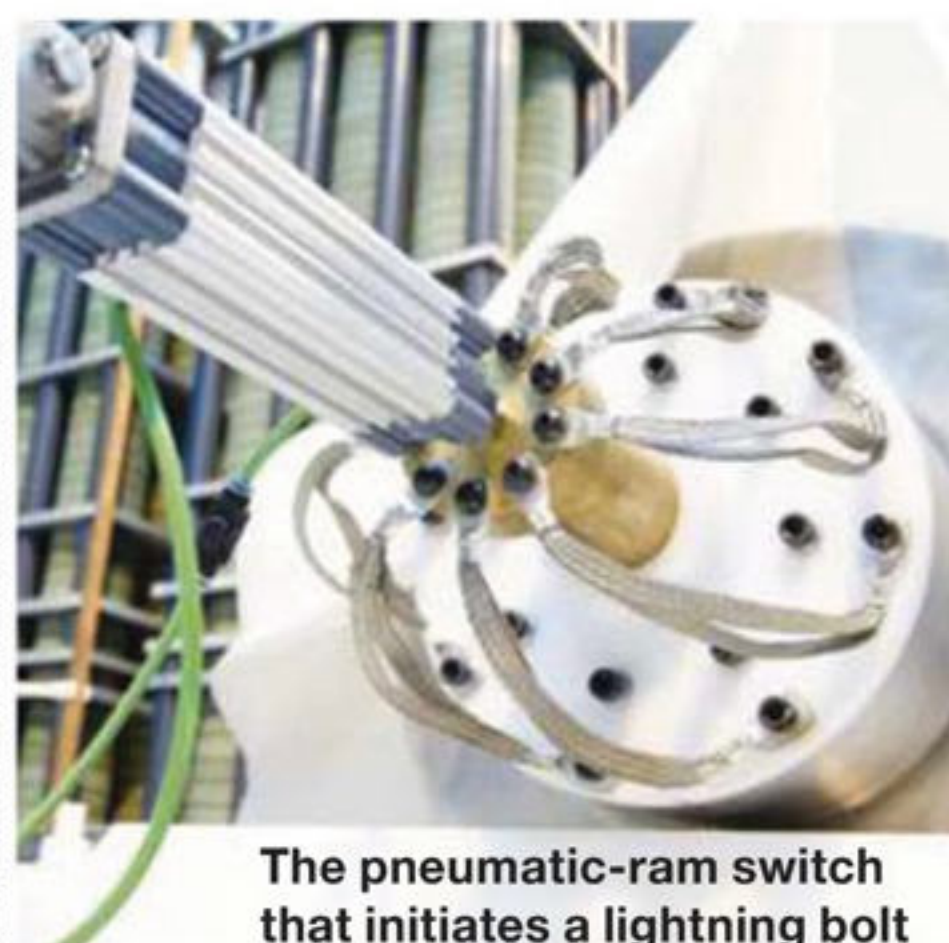
⑤ The current continues on its way through the electrode, along an aluminium return plate and finally through six return cables.

means there's the potential for greater physical damage at the strike point than would be seen with aluminium.

Project manager Chris Stone appears strangely relaxed about placing his finger on one of the giant wires in the circuit that administers the simulated lightning strike. The wire is bare and, at times, carries sufficient amps to turn a portion of his body into carbon. But he should be relaxed: he built the house-sized

contraption, including its extensive safety measures, almost single-handedly over a period of 12 months. So he knows that being on the receiving end of such a jolt is not a possibility. "It's pretty bespoke," he

1
LIGHTNING
STRIKE TAKES
PLACE EVERY
SECOND ON THE
SURFACE OF
THE EARTH



The pneumatic-ram switch that initiates a lightning bolt

says. "It's essentially a giant camera flash unit."

With electrical components the size of logs linked by flat aluminium wires 0.5cm thick and 5cm wide, the circuit makes you feel like a tiny ant crawling inside an old transistor radio – only this one packs a punch more than three times the power of your average lightning bolt. When the lab is upgraded within the next 12 months, it will be capable of delivering up to 250,000 Amps. ►



The capacitor bank builds electric charge



Project manager Chris Stone in the control cabin

91

PEOPLE WERE KILLED WHEN AN INTERNAL FLIGHT IN PERU WAS STRUCK BY LIGHTNING IN 1971. THE SOLE SURVIVOR WAS A 17-YEAR-OLD WOMAN WHO FELL OVER 3KM.

► Lightning is the discharge of pockets of electrical charge that have built up within clouds. This is due to warm air rising and generating friction, which liberates negatively charged electrons from the surrounding atoms. It may take an afternoon for nature to

charge a cloud. In the lightning lab, the charge is built up across a bank of capacitors the size of large bins in less than 20 seconds.

To charge the capacitors, we must leave the vicinity of the giant circuit. Large orange sirens flash as a metal door closes and locks behind us. We don headphones and retreat to an electrically isolated, acoustic-lined control room. Stone fixes his gaze on the readout of the high-voltage charging equipment.

"It's ready to fire," he says, before pressing a button that operates a pneumatic ram that shoots two tungsten electrodes towards one another. Before they even touch, the current leaps across the gap and, in a matter of microseconds, is unleashed into the nearby sample chamber, a closed, room-sized compartment adjacent to the circuit. A short-lived metallic crash echoes around the building. It's time to take a look inside (see 'How to make lightning' on p44).

The target for this particular shot was a piece of carbon composite wing panel joined to a section of titanium support structure – the joint being known as a 'fastener' in the industry. "We're looking for signs of sparking," explains EADS research engineer Simon Evans. "These types of fastener would be in the centre of the wing where the fuel is kept."

WHEN LIGHTNING STRIKES

What happens when a commercial airliner is hit by a bolt from the blue?

INSIDE THE AIRCRAFT

Safely sealed inside the conductive metal shell of the aircraft's body, the passengers and crew are unlikely to suffer anything more than frayed nerves when their plane is struck by lightning. According to one easyJet captain who spoke to *Focus*, there's typically a loud bang and a very bright flash. "Then all my instrument displays changed from colour to black and white," he said of one instance, adding that it is standard procedure to land at the nearest available airstrip once a plane has been struck, just to be on the safe side. "You certainly know that you've been hit."

OUTSIDE THE AIRCRAFT

Lightning tends to strike the extremities of a plane, such as the nose, tail or wings. This turns the aircraft into part of a circuit through which current travels either to the ground or to a pocket of charge with opposite polarity in a nearby cloud. Direct effects include scratches or blackening of the aircraft's



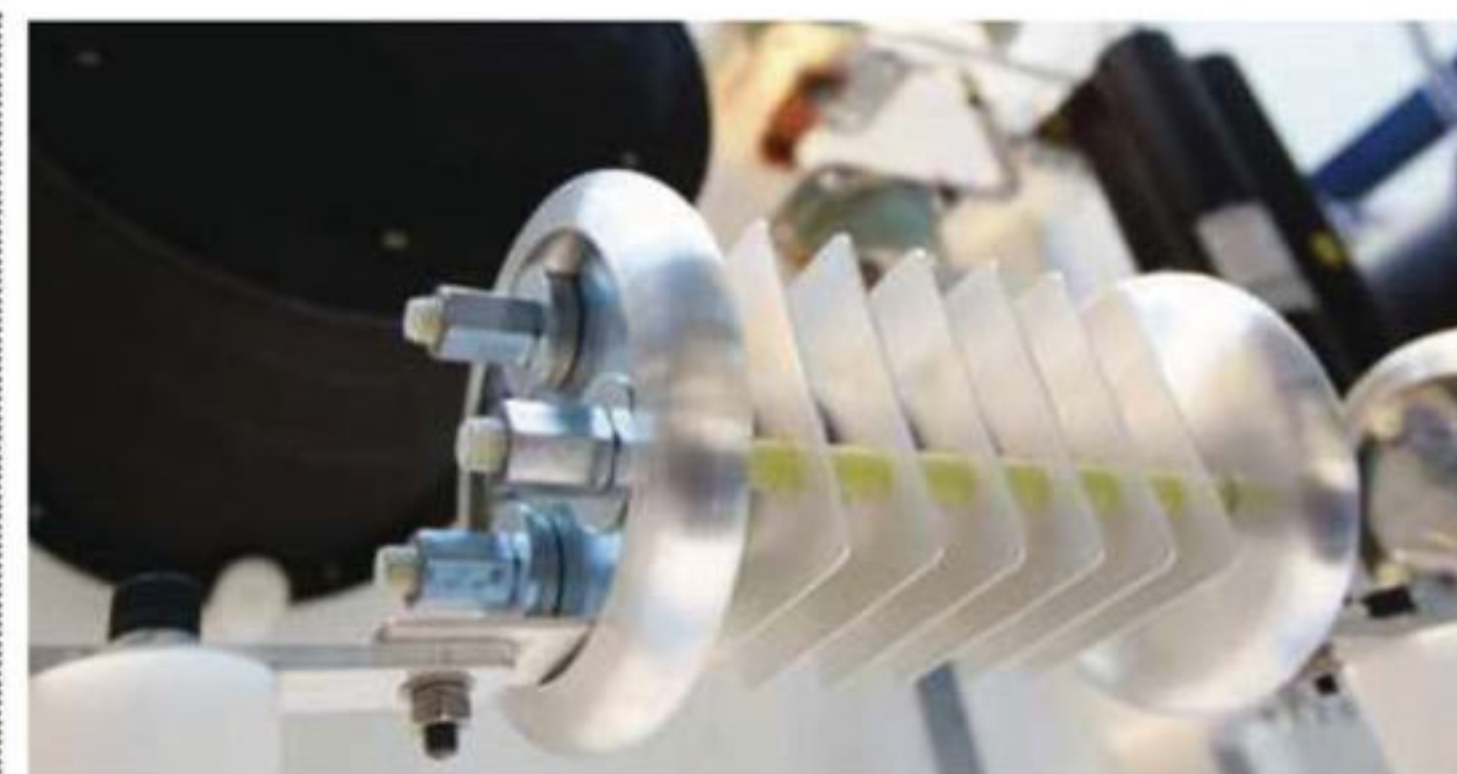
Lightning often strikes the extremities of an aircraft

surface, although some planes have been brought down by lightning. In 1963 Pan Am Flight 214, en route from Baltimore to Philadelphia, crashed in Maryland after being struck. Increasingly stringent design regulations have been introduced so that such damage is extremely unlikely in a modern airliner. That said, smaller or older planes with less lightning protection are more vulnerable.

Less direct effects can occur when the high current causes power surges in the plane's electronic systems. The nose presents a unique challenge because it conceals the aircraft's communication system, the radar, without which it would be practically impossible to navigate or land. The nose cone can't be made from a conductor because the radar system wouldn't work, so instead it is made from an insulating material lined with conducting fins that guide the current safely into the fuselage.

Unlike in metals, where holes can be drilled and rivets punched through to join components together, drilling holes through composites can produce stray strands of fibres which, when the electric field on the surface is high enough, may create a discharge. Not great news if these strands are next to a few thousand gallons of fuel. Manufacturers are therefore developing new joints – pushing hooks on the surfaces of the titanium supports directly into the carbon fibre.

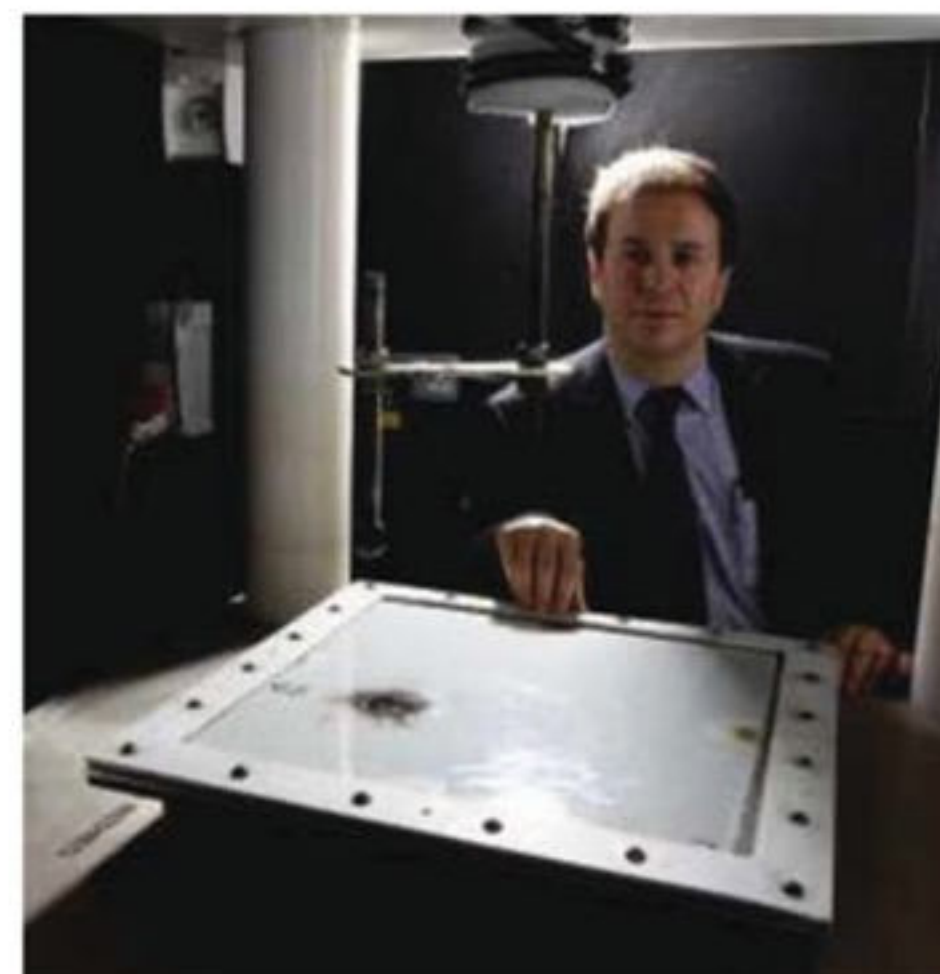
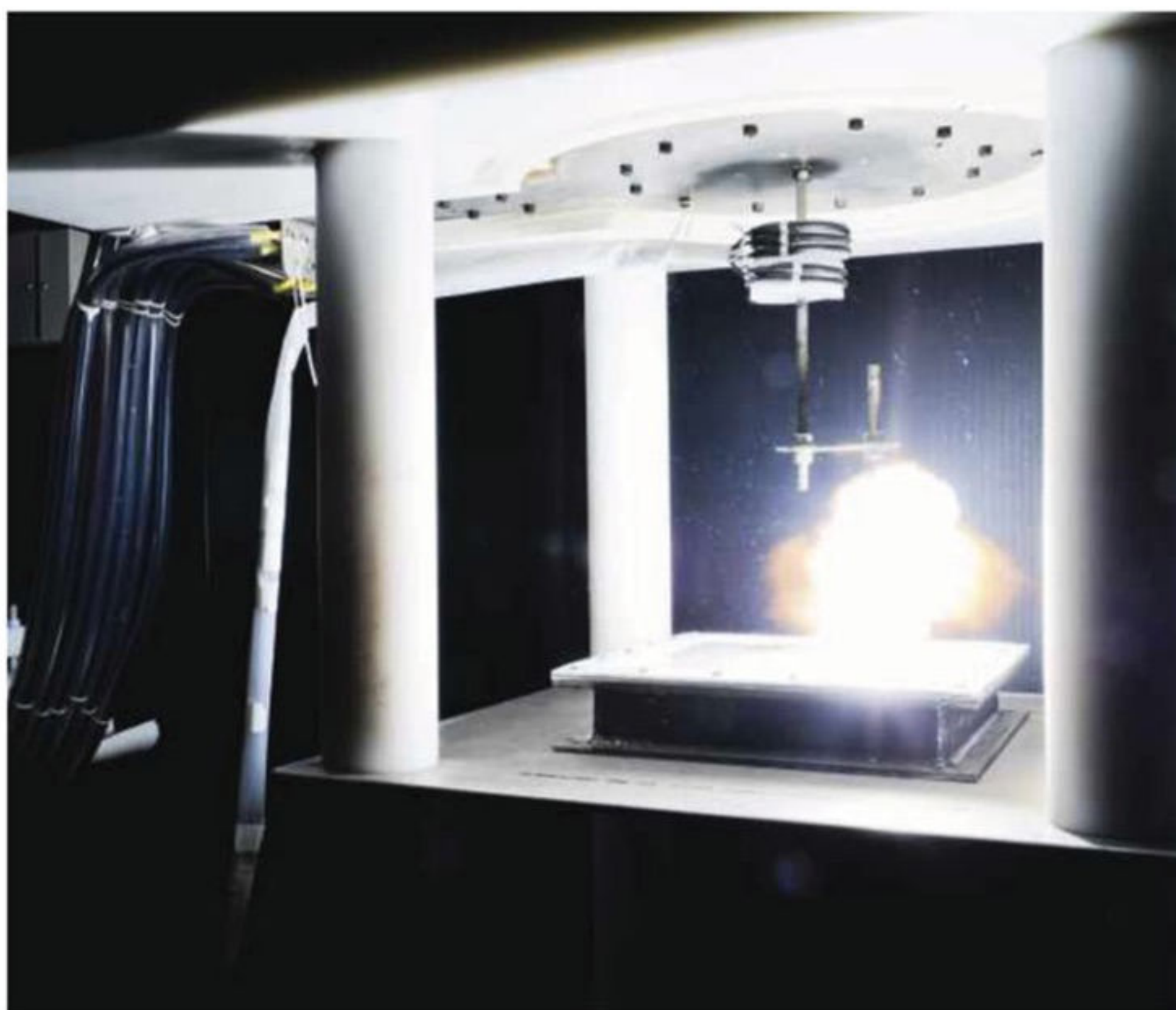
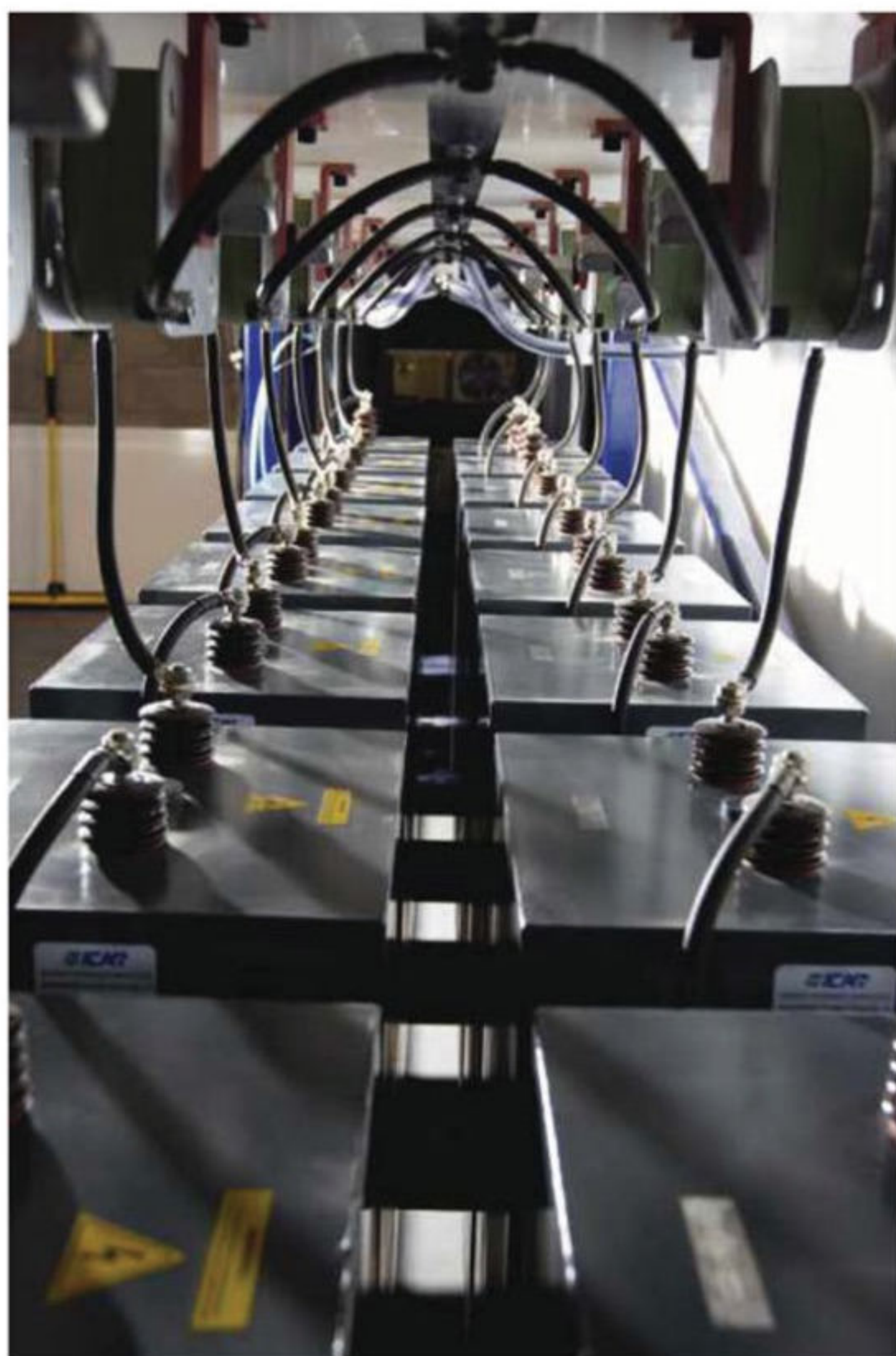
A bitter stench of burnt carbon hits us as the door of the sample chamber opens. Stone switches on the extractor fans and lifts the cloth draped over the target stage. The thin tungsten wire that once linked the circuit to the live plate to produce the lightning arc is no longer there. Under the intense



A protection diode for preventing feedback through the circuits

electrical load, it has evaporated. Stone retrieves the blackened sample, which to the untrained eye hasn't fared too well.

"This is a research item," says Evans as we inspect the damage. "It's not a true representation of an aircraft component since there's no lightning protection, so we'd expect something like this to happen."



10
PER CENT OF
LIGHTNING
STRIKES HIT THE
GROUND – THE
REST TAKE PLACE
BETWEEN
CLOUDS

But creating lightning in the lab is a rather more practical approach, with new bolts fired every 30-60 minutes. "In our work we aim to make the epoxies more conducting using additives," says Haddad. Even the types of paints and coatings applied to aircraft bodies can influence how

Haddad's dream is to fly in a composite aircraft hit by lightning. "I'd like to feel what it's like for the passengers and take measurements so I could investigate the effects at the lightning's entry and exit points," he says.

they respond to lightning, so new ingredients are being investigated.

SUPER BOLTS

In the past few years, scientists have become aware of mega-lightning bolts called sprites that carry currents perhaps hundreds or thousands of times larger than conventional strikes. "Nasty lightning," says Stone, shaking his head. Thankfully today's aircraft and the next generation of composite planes will be well out of the way of sprites, which occur in the very upper atmosphere and head upwards like flares.

But in the longer term, aircraft are likely to touch the edge of space, allowing the travel time between London and Sydney to be slashed to just four hours. The designers of these space planes may want to take

Clockwise from left: a bank of capacitors ready for charging; the bright flash of a synthetic lightning bolt; Prof Haddad with the lightning machine; the effect of a 100,000 Amp shock on a carbon composite

note of the research taking place in Cardiff – carbon composites and other advanced materials will be a vital part of making such travel possible. If they don't get their composite materials right, it will take a lot more than a stiff gin and tonic to deal with the shock of a sprite strike. ■

Matthew Chalmers is a science writer with a PhD in physics

FIND OUT MORE

BBC

bbc.in/Ms2S1a

BBC transport correspondent Richard Westcott visits the Morgan-Botti Lightning Laboratory

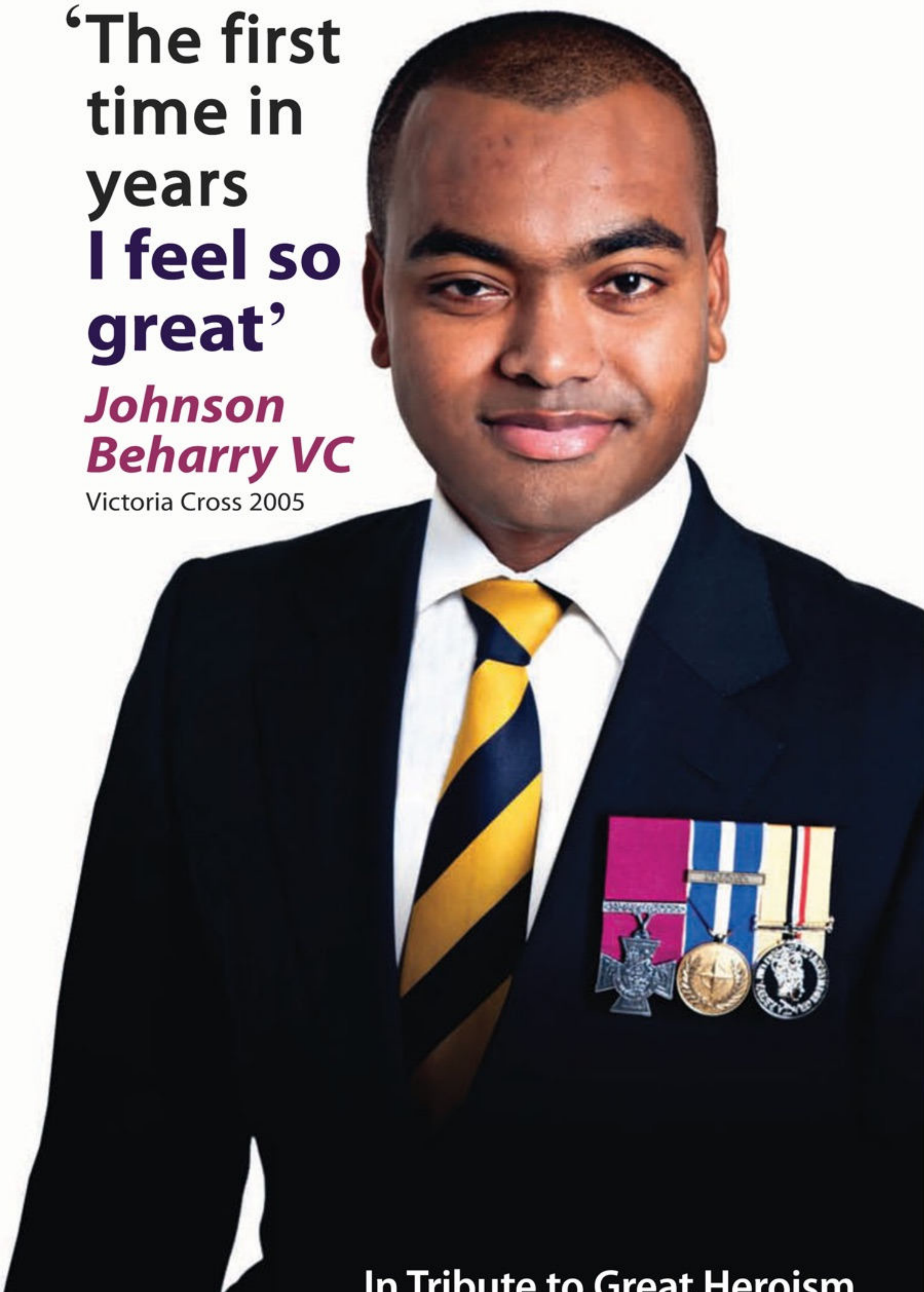
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EADS video about the lightning lab

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time in
years
I feel so
great'**

**Johnson
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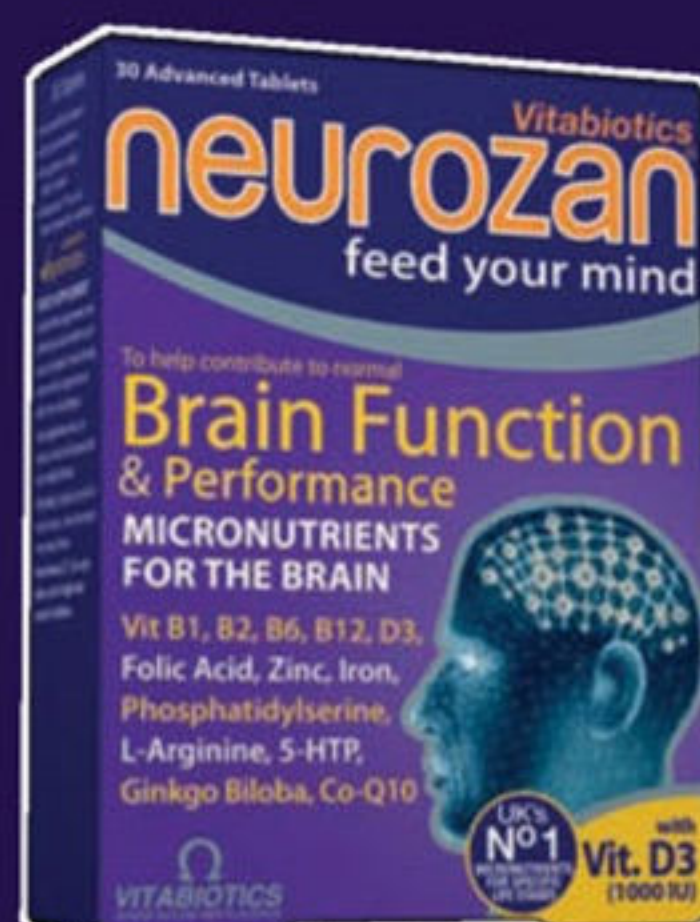

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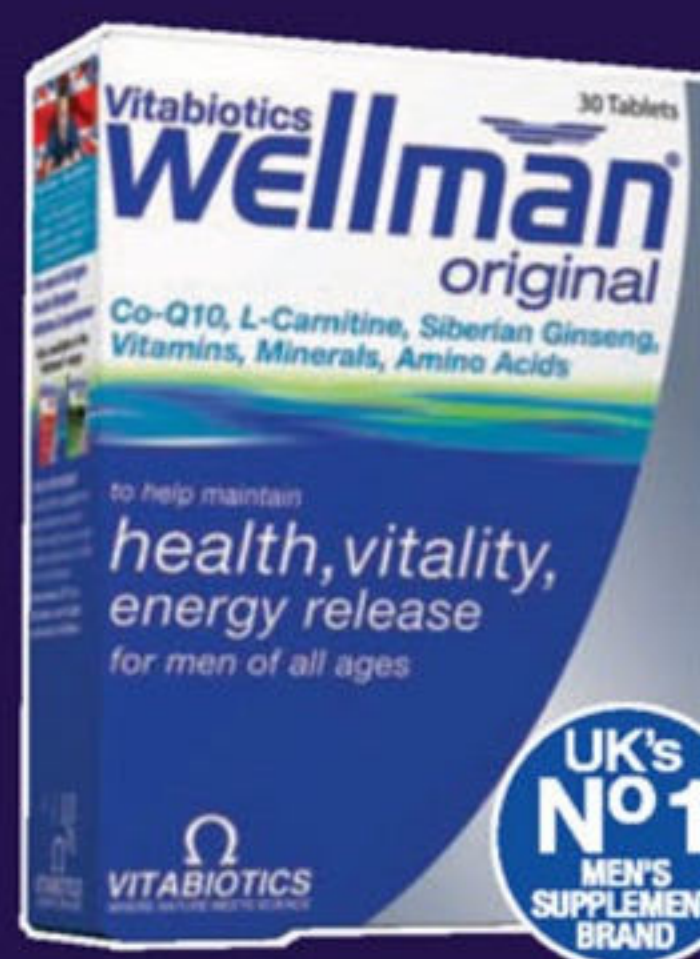
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OPERATION ICEBERG

Scientist and BBC presenter **Dr Helen Czerski** reports from Greenland on an expedition to track the journey of an Arctic iceberg

Accompanies the
BBC Two series
Operation Iceberg



Ask a child to draw a lake, and they will use a blue crayon. Bright blue. And the same goes for the ocean or water in the bath. But that's odd, isn't it? Lakes are brown-ish, green-ish or at their best, blue-ish. Our mental image is of something we've never seen. But two weeks ago, I stepped out of a helicopter on to a glacier and just in front of me was the azure lake of my childhood artwork. It was as if someone had poured the world's supply of blue food dye on to the ice.



A family of Arctic foxes became increasingly curious with the expedition, as well as a host of Arctic mosquitoes



► This spectacular sight was the start of our scientific journey on the Store glacier in Greenland for the BBC Two series *Operation Iceberg*. There are many of these lakes up on the glacier, formed as the summer Sun melts the surface ice and the meltwater droplets find their way down into the nearest hollow. As the season goes on, the

lakes grow. We were clambering about over the lumpy ice to install water level sensors and a time-lapse camera to monitor that growth. And it is just water – the sensational blue colour is the result of a very pure situation. Water absorbs red quickly, and green light nearly as quickly, leaving the blue wavelengths until last. Since

there's only reflective white ice on the lake floor, the light that finds its way back out of the lake is almost perfect blue.

The lakes don't last. The glacier is a moving fortress of ice, constantly shuffling and creaking as it marches from the centre of the Greenland ice cap downwards towards the ocean. As it goes, immense internal forces can open up crevasses and fractures. If this happens at the floor of a lake, it's like pulling the plug in the bath. The entire lake disappears down the plug hole and into the glacier. So of course, while we were interested in the lake growing, there was also the tantalising (and dangerous) possibility that it would start to drain while we were there. I have never before spent a morning keeping an eye on a lake in case it runs away, and it definitely made me feel very small and vulnerable.

The mosquitoes, on the other hand, made me feel very large and vulnerable. My skin is a gourmet dinner buffet for an Arctic mosquito, even when I'm covered in many layers of clothes. We spent three weeks camping on a small rocky plateau overlooking the front of the glacier, and on the still days we all felt like pin cushions. Apart from the occasional hare and the increasingly nosey Arctic foxes, we were the only



Cryoconite holes betray the presence of volcanic dust, which absorbs more sunlight than the ice



Dr Helen Czerski and the crew were hoping to see an iceberg calve off a glacier



Streams of meltwater snake away before plunging into the depths of the glacier

mammals there and our small buzzing companions took full advantage. At least we gave something back to the local ecological economy.

Every iceberg has a long history, and that history always starts at a glacier. We were at Store to follow and help with the ongoing scientific experiments that are revealing the details of iceberg formation. Our campsite felt like a tiny but very multidisciplinary village, with about 20 production crew, scientists and presenters. The kitchen tent had a prime spot overlooking the white cliffs of ice where the glacier met the sea, and at mealtimes everyone would perch on the rock next to it to eat.

GLACIAL GLORY

The lifestyle was fairly primitive, but the setting was spectacular. The glacier squeaks, creaks and booms as it shuffles along, and we would often see mini avalanches of ice tumble off the front and into the water. Sometimes these heralded much larger calving events, as vast chunks of solid ice separated from the cliffs and started their journey out to sea. Dinnertime entertainment was mixed with professional interest, as we kept an eye out for the event we really wanted to see – the calving of one of the largest icebergs that Store glacier can produce.

Operation Iceberg will be a two-part series, and the first programme covers the glacial science leading to iceberg formation. The topic of the second programme is icebergs at sea, and how these behemoths of the ocean eventually break up and melt away. The best bit about this for me is that I get to help with the research as well as being a presenter. This project is a really interesting and symbiotic collaboration between researchers and programme-makers – neither would be here without the other.

I study the physics of the ocean but I have also worked on the physics of materials, so an iceberg has the perfect subject combination for me. I love the idea that there are hidden processes just underneath the surface of familiar objects, and this project is keeping me happy because ice is full of hidden mysteries.

Some of the processes influencing iceberg formation start many kilometres up the glacier. When you're on the ice, hints about the complexity of what you're standing on are everywhere. My two favourite things were the very blue streams of melt water, and some lovely things called cryoconite holes. The meltwater streams snake around like water slides before suddenly disappearing down into deep holes, gateways to the

"Every iceberg has a long history, and that history always starts at a glacier"

internal plumbing of the glacier. The cryoconite holes are beautiful pockets in the ice, reminiscent of the holes in Swiss cheese. At the bottom of each one lies a black layer of volcanic dust, which is responsible for the hole it's in. The black dust absorbs more of the Sun's energy than the ice, warms up and melts itself a perfectly-shaped deep hole. It's a stunning demonstration of how an object's colour controls how well it absorbs energy from the Sun.

The blue lakes aren't just pretty cartoons come to life. They are one of the many cogs in the fascinating machine of glacial mechanics. My three weeks on Store glacier changed my perspective on icebergs almost completely. Did the lake drain away? Did we see a giant iceberg calving? You'll just have to tune in to *Operation Iceberg* this autumn to find out. ■

Dr Helen Czerski is a physicist, oceanographer and BBC presenter

**BBC
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Colin Farrell as Doug
Quaid tries the Rekall
memory machine in the
new film *Total Recall*



The **MASTERS** of **MEMORY**

The new movie *Total Recall* depicts a world in which we can alter memories. Psychologist **Charles Fernyhough** investigates how close reality is to science fiction

With electrodes attached to his head, Doug Quaid lies back in the machine at Rekall, a company offering to implant memories of exciting new experiences in his mind. “Tell us your fantasy – we’ll give you the memory,” says the sinister technician, in a scene from this month’s remake of *Total Recall*.

But what does science tell us about the plausibility of manipulating memory? One thing we’ve learned from decades of research in psychology is that memory is malleable, and findings from neuroscience support the idea that memories aren’t immutable recordings of the past. What’s more, teams of scientists around the world are now finding ways to manipulate memory – with startling results.

“Memories are usually reliable when we’re recalling the general gist of a personally experienced event – our first kiss or our last birthday,” says Nobel prize-winning biologist Susumu Tonegawa. “However, recalling a memory is not just a reproductive process of what happened, but a reconstructive process – meaning that we inevitably add new details and sometimes even entire events that were never really experienced in the first place.”

Based on a story by science-fiction author Philip K Dick, *Total Recall* ►

► promises to get us thinking about how our identities are founded on what we can remember. In the futuristic film, technology and drugs are used to erase a person's memories and implant false ones. It's a common theme in sci-fi films. We've seen a multitude of methods to manipulate memory in movies, from a flash of light – *Men In Black's* Neuralyzer – to the virtual training in *The Matrix*, in which the martial art kung fu is downloaded into Neo's brain.

Making memories

The 'memories' implanted into Quaid's mind in *Total Recall* would count as autobiographical memory: the memory of events and experiences from one's own life. Ask someone how they think this works and they'll tend to liken it to a video camera, recording events and storing them in fixed representations that can be replayed at a later date. If memory was like a videotape, the idea that it could be wiped clean would follow naturally.

Autobiographical memory can certainly feel like replaying or reliving the past, but the video-camera analogy is misleading. When you recall an event from the movie of your life – such as your best friend's wedding – you don't reach into a mental DVD library, pull out the disc marked 'Dodgy dancing in the marquee' and press play. Rather, your brain reconstructs the event based on several different sources, starting with whatever information was the cue for the memory. Influenced by what you know at the moment of recall, you draw together facts, add sensory and perceptual impressions of how the scene looked and felt, and finally stick all the pieces together into the multimedia collage we call a memory.

The powerhouse of this entire operation is the hippocampus, a pair of horn-shaped structures on each side of the brain, the main function of which is to store associations between different bits of information (see 'Memory sticks', p57). Zoom-in

closer and this involves strengthening connections between certain neurones, a phenomenon known as long-term potentiation (LTP).

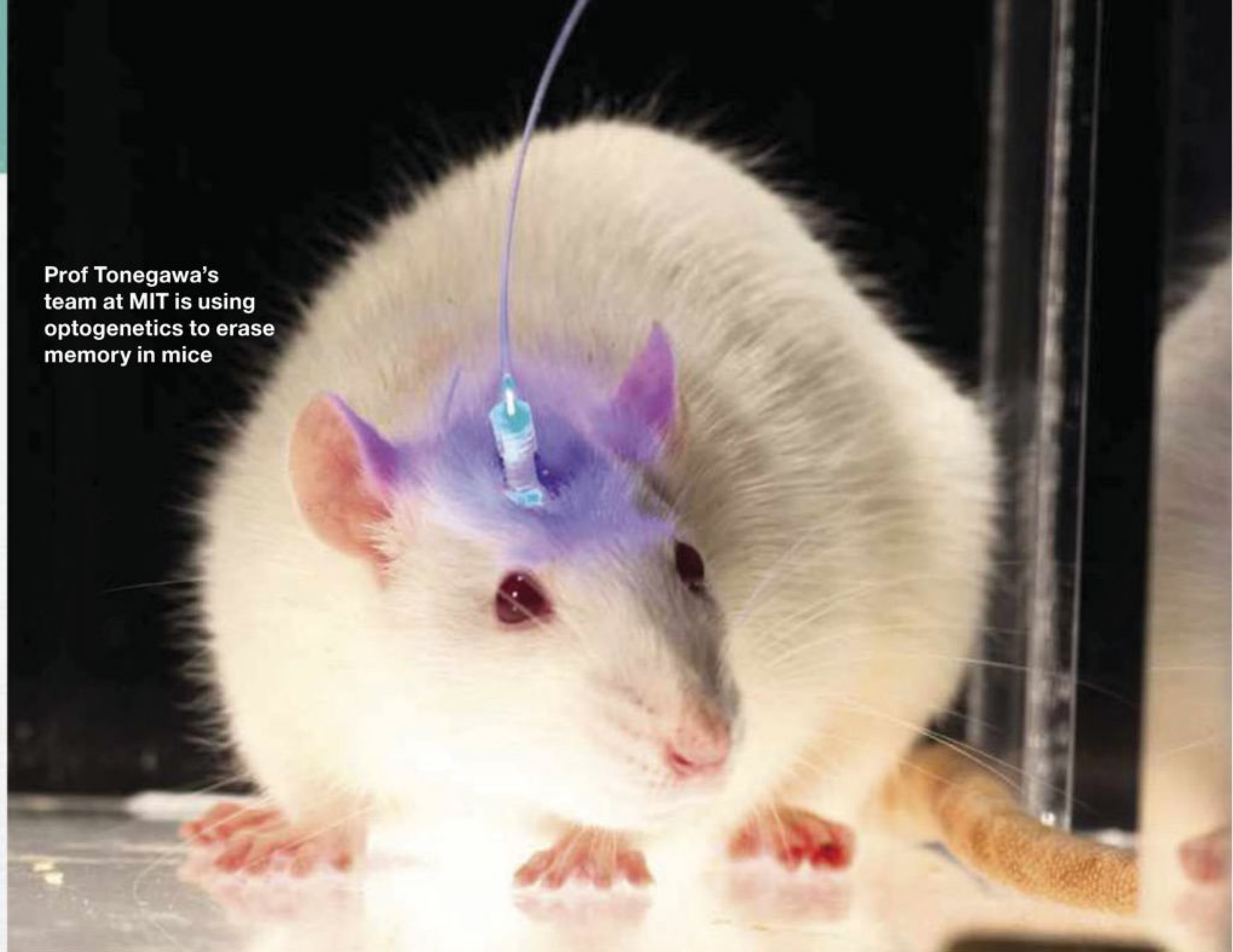
But even these permanent-sounding changes are susceptible to being altered by subsequent experience, as demonstrated in a classic experiment at New York University by neuroscientist Karim Nader. After teaching rats to fear a mild electric shock by pairing it with a high-pitched noise, Nader injected the animals with anisomycin, a drug that blocks the formation of new memories. When the rats later

heard the noise, they wouldn't flinch in anticipation of a shock: the drug had effectively made the rats forget their fear.

Nader had shown that the biochemical changes involved in making memories are also necessary for retrieving them – a long-

term memory isn't only consolidated once it's first formed through LTP, it's also reconsolidated during recall. In the movie of your life, this means you don't

Prof Tonegawa's team at MIT is using optogenetics to erase memory in mice



Don't look at the light! *Men In Black's* Neuralyzer

MEMORY STICKS

The science of forming, saving and losing memories

simply re-watch a scene. Your brain has to take the actors, set and script, then re-shoot the scene every time you remember them.

Scatter brain

If memories are so mutable, doesn't that make manipulating them more plausible? The hard part is how to pin down an *individual* memory.

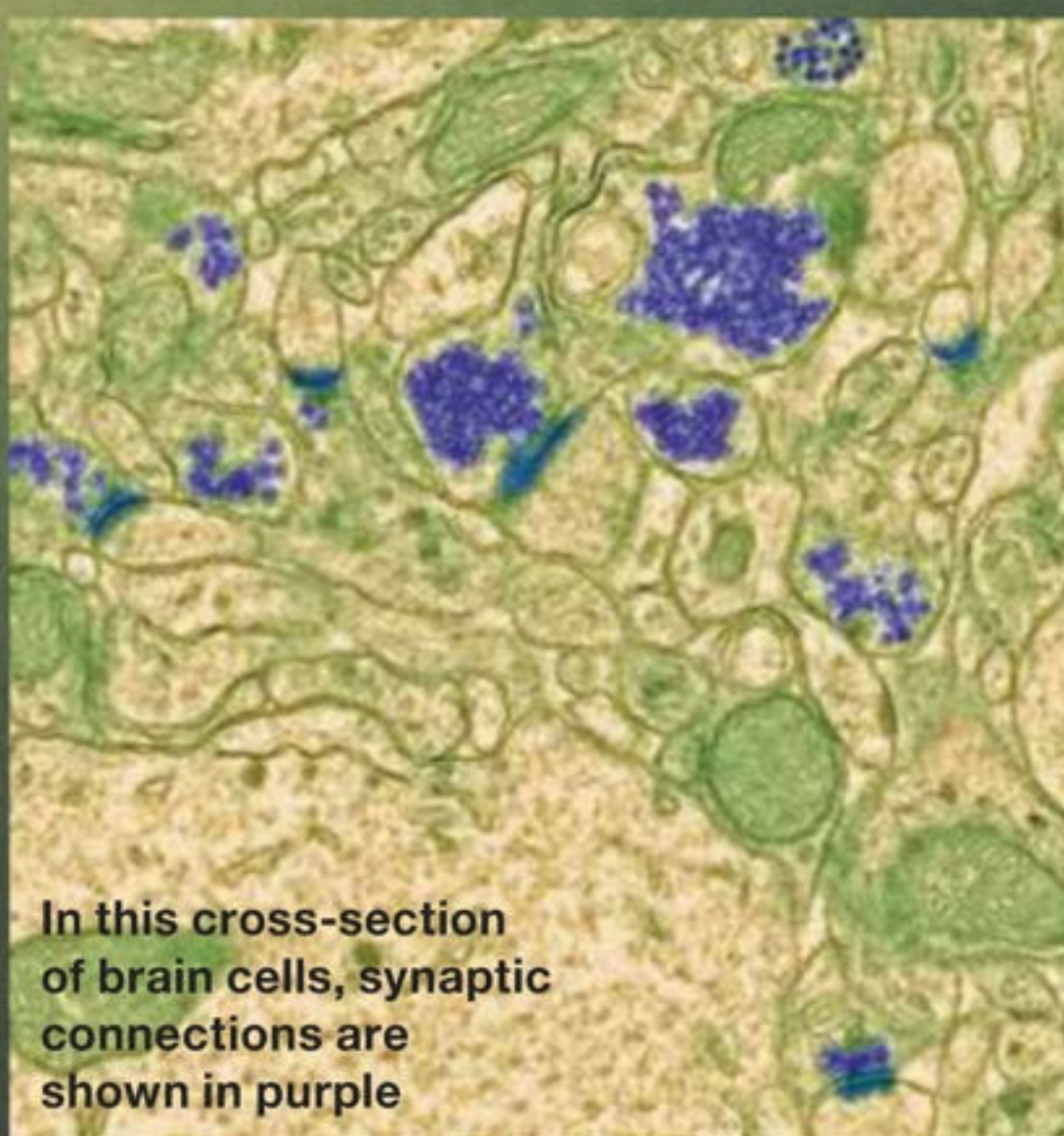
According to the reconstruction theory, autobiographical memories aren't distinct entities, but mosaics. The information the brain draws on to create a memory is scattered among its neurones and assembled in subtly different ways each time an event is remembered. The much-sought engram – the physical trace that an individual memory is supposed to leave in the brain – has remained elusive, and trying to delete a memory would involve tracking down a lot of disparate traces.

But some neuroscientists claim to have done just that. Taking a drug that blocks the LTP process and injecting it into the hippocampus of rats, Todd Sacktor of SUNY Downstate Medical Center in New York has shown that the animals can be made to 'forget' a learned aversion to a particular location where they had previously received an electric shock. The drug, ZIP, inhibits the synthesis of an enzyme called PKM-zeta – a 'memory molecule' that's essential for strengthening neural connections.

The trouble with such approaches is that they're scattergun: they mess with all memories in an untargeted way. What's needed is to leave everything else intact. But it's a daunting prospect. The human brain consists of 86 billion neurones working together to create the richness of our personal experience, firing electrochemical signals in specific patterns across distinct brain regions via a tangled web of connections. "The greatest challenge is pinpointing only the small fraction of cells that are actually responsible for holding onto our memories," explains Prof Tonegawa. ►



Long-term memory can last for decades



In this cross-section of brain cells, synaptic connections are shown in purple



You will struggle to recall a memory if cues such as a sound or smell aren't encoded in the brain

WHAT IS MEMORY?

Whereas short-term memory lasts seconds, long-term memory endures for minutes, months or decades. Aspects of long-term memory are then further categorised as 'semantic memory' (for facts) and 'episodic memory' (for events). Forming an episodic memory involves three different stages: encoding (the initial laying-down of its physical trace in the brain), storage (preserving the associations between connected brain cells) and retrieval (reconstruction of a remembered episode from its constituent parts). Episodic memory typically occurs in conjunction with 'autonoetic consciousness': the sense people get of travelling back in time to re-live the moment. Autobiographical memory – our personal experiences – is a specific form of long-term memory that involves both episodic memory for life events, plus semantic memory about how our lives have unfolded.

HOW ARE MEMORIES STORED?

In neuroscience, the basic mechanism is called long-term potentiation (LTP). This involves neurones 'learning' to fire electrical signals in sync, so that when one brain cell is firing, it also triggers the activation of a second, connected neurone. Connections between neurones occur at the gap between the cells – the synapse – and require the synthesis of special enzymes, including the 'memory molecule' PKM-zeta, which strengthens the neural connections. Neurones in the hippocampus are particularly important in the laying-down and subsequent reactivation of connections needed for memory. However, the pieces from which an individual memory is assembled are probably stored in separate areas of the cortex: the occipital cortex (at the back of the brain) for visual information, and the auditory cortex (in the temporal lobes) for sound.

WHY DO WE FORGET?

There are many reasons why an autobiographical memory might not come back into consciousness. The basic reason for losing a memory is a failure of long-term potentiation. In such cases, consolidation – stabilising the memory by strengthening the neural connections – never occurs, so it never makes the transition from short to long-term memory. Another important factor is whether the cues that were present at the moment of encoding, such as perceptual stimuli, match up with the cues present at the time of retrieval. When a memory is laid down, perceptual stimuli are incorporated into the network of neural associations that end up being stored. That's why returning to a familiar place can trigger old memories associated with that location. But if the right cues aren't around at the moment of recall, the memory is effectively forgotten.

TOTAL RECORD

Cameras could accurately capture autobiographical memories

While *Total Recall*-style techniques like brain stimulation are still some way off, much simpler technologies could soon improve our ability to recall things that happen to us. Given that remembering is so dependent on matching cues for storage and retrieval, one option is to use digital technology to record how events appeared to us, in the hope that they'll later serve as cues to memory.



Achieve total recall with the Microsoft SenseCam

WHAT TECHNOLOGY IS AVAILABLE?

One such device is Microsoft's SenseCam, a lightweight portable camera originally developed as a tool for 'lifelogging' – the trend for people to use digital devices to archive their daily activities in fine detail. Worn around the neck on a lanyard, SenseCam takes pictures on a fixed time schedule, or in response to movement or changes in lighting. Although the resulting images are low-resolution, this automatic capturing means a lifelogger can get on with their business without having to keep stopping to take snaps. You can buy the SenseCam as the Vicon Revue.

HOW COULD CAMERAS BE USED?

Lifelogging cameras quickly came to the attention of neuropsychologists working with amnesia patients. To test the idea that cameras could help form memories, patients have been asked to wear a SenseCam when they know they're going to have an interesting new experience, then upload their images to a computer and review them shortly after the event. Such studies show that reviewing the images can help patients retain memories of events that would otherwise be forgotten. Although no-one argues that the technology can 'cure' amnesia, it seems to have a useful therapeutic effect.

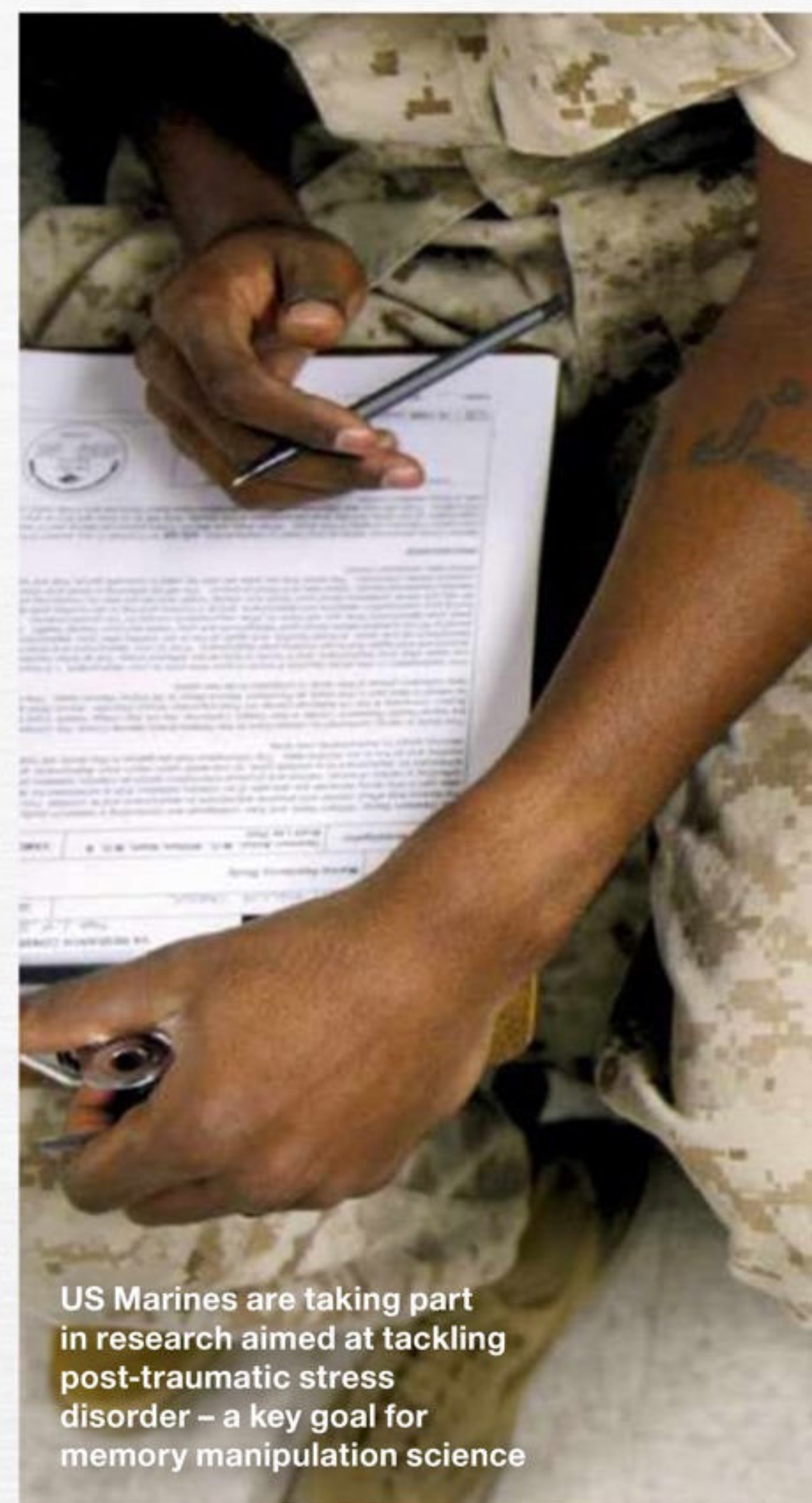
DO PICTURES IMPROVE MEMORY?

One possibility is that images preserve a person's original field of view, enabling closer matching between the encoding and retrieval cues. And because SenseCam has a wide-angle lens, it also captures visual details that an ordinary camera would miss. Users with amnesia report that the tiniest details can trigger a cascade of recollections, while non-patients say it helps them to notice details of their lives that would otherwise go unremarked. Even if they don't improve the power of our memories, such technologies can help us to become a little more aware of the lives we're living.

► At the Massachusetts Institute of Technology, Tonegawa uses a sophisticated new approach to pinpoint a specific memory. His team first identifies which cells of the hippocampus are activated when a mouse forms a memory. In this case, the memory is learning to fear a dangerous new environment – activated neurones cause the mice to freeze in response to a particular location. These cells are tagged with light-sensitive proteins, then attached to a tiny optical fibre to shine light on the mouse's brain (see image on p56).

This revolutionary technique, 'optogenetics', allows the researchers to stimulate or stop mice from 'remembering' to freeze – just by illuminating the cluster of neurones associated with the fear response. "Our work involves tricking these brain cells to turn on or off in response to pulses of light, either activating or temporarily inhibiting a specific memory," explains Tonegawa. "That is full mind control, *Total Recall*-style, plucked from the tree of science-fiction and grounded in the reality of research experiments."

Results such as these, along with the potential development of a 'forgetting pill' – a drug that blocks memory molecules like PKM-zeta – have led to some heady claims about how we will soon be

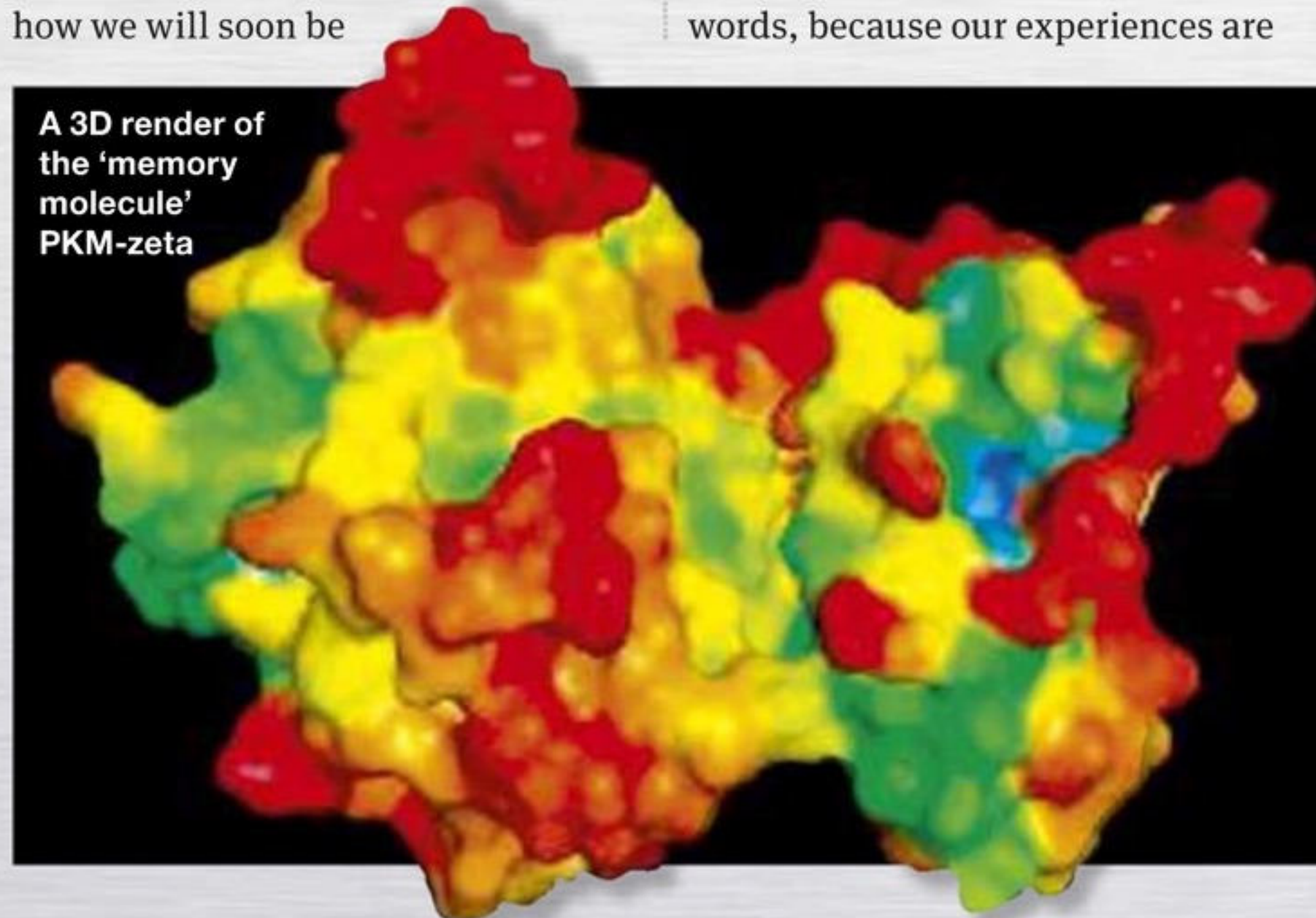


US Marines are taking part in research aimed at tackling post-traumatic stress disorder – a key goal for memory manipulation science

able to edit or erase addictions and painful experiences.

Can such precise manipulation ever be applied to the complex, multimedia reconstructions of episodes in autobiographical memories? Dr Amy Milton, a neuroscientist at Cambridge University, urges restraint. "While it might be possible to pin a fear memory down to a specific part of the brain, episodic memories [see 'Memory sticks', p57] are much more distributed," she cautions. In other words, because our experiences are

A 3D render of the 'memory molecule' PKM-zeta





"That is full mind control, pucked from the tree of science-fiction"



scattered around the mind, erasing a memory is more fiddly than simply deleting a computer file.

Imminent implants?

The picture looks a little different when it comes to implanting new memories. In fact, cognitive psychologists have been doing this for decades. "I study memory distortion," says Professor Elizabeth Loftus of the University of California, Irvine. "From experimental studies, I've shown that people can be led to believe they saw and did things that they haven't."

Loftus typically shows participants a movie of an event, then exposes them to things that don't match what they actually saw. People frequently incorporate this misleading information into their memories of the event, raising serious doubts about the validity of eyewitness testimony. In the most striking demonstrations of this 'misinformation effect', researchers have been able to implant what they call 'rich false memories' – vivid and detailed fictional episodes, such as getting lost in a shopping centre.

Social factors are particularly powerful in the misinformation effect.

We manipulate each other's memories all the time, just by talking about the past. Siblings – particularly twins – often claim each other's memories as their own, and neuroimaging techniques have helped identify bits of socially-transmitted information that will go on to form part of a 'genuine' false memory.

Biologists are also making progress with implanting false memories. Mark Mayford of the Scripps Research Institute in California has genetically engineered mice that recall a location after being injected with a drug called CNO. Placed in two environments in succession, these mice should normally form two distinct memories: box 1 was safe, whereas box 2 contained a small electric shock. But injecting the drug before mice were put in box 2 activated a strong memory of box 1, preventing the animals from forming a clear memory of box 2 and learning a fear response. Instead, the mice seemed to develop a mixed-up memory combining both locations. This hybrid environment doesn't really exist – it's a false memory.

Science is still a long way from achieving the sci-fi scenario of *Total*

Recall, but it's worth pursuing. Quaid visits *Rekall* because he fancies a change of scene, but there are very good reasons to alter our memories.

People who have experienced severe trauma sometimes develop post-traumatic stress disorder, a condition characterised by intrusive 'flashbacks' of events. By giving sufferers drugs like propranolol, which interferes with the consolidation of a memory, while they're reliving traumatic events, the emotional power of memory is reduced. The goal of therapy in these cases isn't to erase the memory, but to reduce its emotional salience.

What about relatively healthy individuals? When Prof Loftus asked people whether they'd take a (hypothetical) drug to erase a memory, 80 per cent said that they would not. Even some of the scientists wouldn't consider manipulating their memories. "Just as I'm not willing to subject myself to cosmetic surgery for physical changes, I'm not willing to have my mental hallmark artificially altered," says Prof Tonegawa. "The memories I possess define who I am, and what makes me *me*."

On another level, we're constantly influenced by the memories of other people through conversations, and we re-shape our accounts of past events to incorporate new information. So in a way, we don't really need *Total Recall*'s futuristic tech: our memories are already a kind of fantasy. ■

Dr Charles Fernyhough is a psychologist and author of *Pieces Of Light: The New Science of Memory*

FIND OUT MORE

See SenseCam in action on the BBC Two programme *James May's Big Ideas* <http://youtu.be/Moxqfeg8dal>



Listen to *Erased Memories And Spotless Minds*, a BBC Radio 4 programme with Dr Mark Lythgoe, at <http://bbc.in/EraMem>



Visionary architects like Vincent Callebaut, whose Lilypad floating city concept is shown here, are drawing up plans for real-estate on the ocean

Rise of the FLOATING CITY

Living at sea could solve a host of problems. **Paul Parsons** investigates the technology that could make it happen

The Sun is rising. You gaze out from your cabin upon the blue-green water that stretches as far as you can see in all directions, a cloudless sky arching high above. The bright sunlight has woken you early. And no bad thing – you’ve a lot to get through at the office today. For this is no holiday destination or luxury cruise liner. No, this is the start of another day as a citizen on board a seastead – a bustling city on legs, situated in the ocean many miles from the nearest dry land.

Not so long ago pioneers could strike out from established civilisation, conquer unexplored lands and build new settlements – which might, given a little luck and a few centuries of hard work, grow into whole new nations. But no more. Today, our planet has no unexplored lands left to conquer. Which is why a not-for-profit think tank in California calling itself The Seasteading Institute (TSI) is pushing to expand the frontiers of civilisation in a different direction altogether, out across the other 70 per cent of the Earth’s surface – the open ocean.

FIRST ATTEMPTS

Seasteading isn’t a new idea. Back in the 1960s, former British Army Major Paddy Bates and his family took over a disused gunnery platform in the North Sea. Despite protestations from the government, the platform is still occupied by the Bates family today – under the title ‘Principality of Sealand’. And in 1972, a group of libertarian idealists established the ‘Republic of Minerva’ – an attempt to forge a society free from government intervention – on a reclaimed atoll in the Pacific Ocean.

But no-one has ever attempted anything on quite the scale that TSI is advocating. “We envisage communities starting small, but quickly scaling up into dynamic cities with thriving populations of millions of people,” says TSI spokesman Charlie Deist. ►

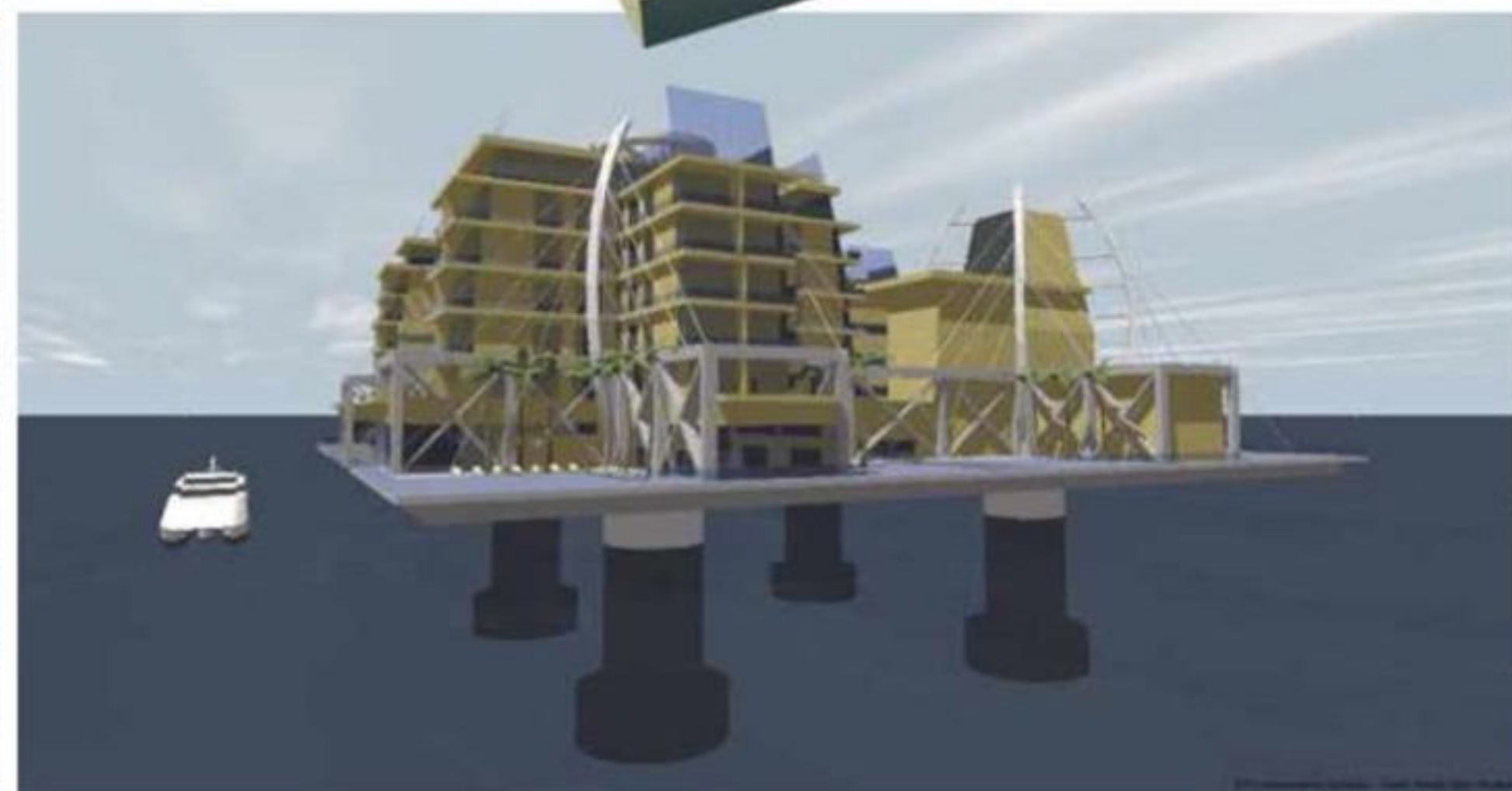
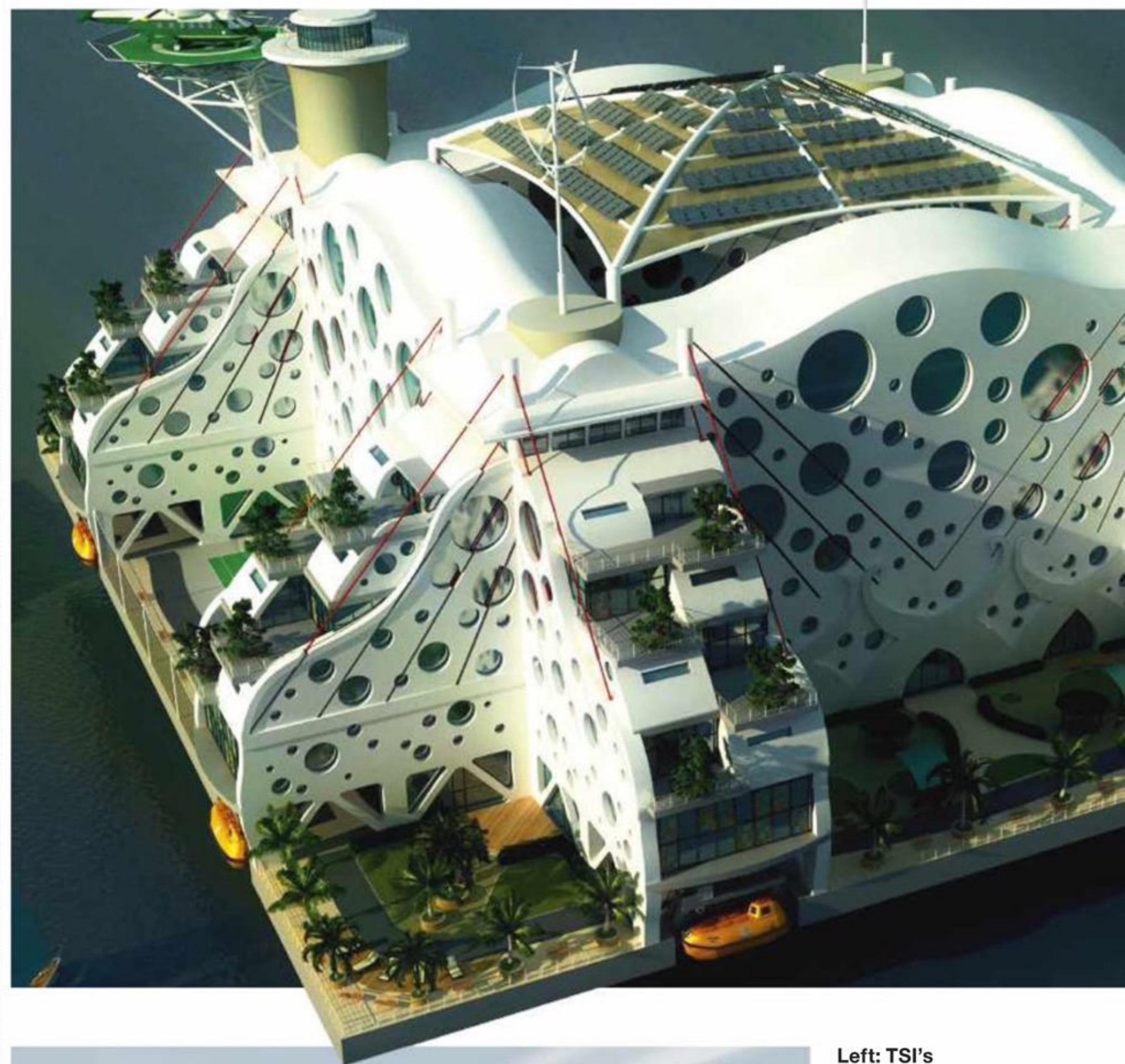
► Financial backing for such projects is already materialising. Billionaire businessman Peter Thiel, one of the co-founders of PayPal, has put \$1.3m (£830,000) of his own money behind the TSI and its goals. The organisation itself was founded by Patri Friedman, grandson of the famous late economist Milton Friedman. Much of TSI's vision resonates with Milton's ideas. "We are eager to see seasteads experiment with a wide variety of political ideas in order to find out which are most desirable to their residents," says Deist. "As long as residents are free to leave, we are not opposed to any political doctrines seasteads attempt to implement."

But it will take many years before a seastead is ever recognised as a sovereign state, able to run its own government. In the shorter term, it will fly a 'flag of convenience', exploiting the open registry that currently enables ships from one nation to be registered with another and fly that other nation's flag. That nation's laws will apply.

One company, Blueseed, founded by two former TSI executives, hopes to launch its own seastead by early 2014, flying the Bahamas flag. Its vessel will anchor 19km off the coast of California, offering a place of work for entrepreneurs and scientists wanting to launch tech businesses, but who are unable to obtain US work visas. Ferries will operate between the Blueseed seastead and the mainland, and internet links between this 'Googleplex of the sea' and the land will be maintained by high-speed laser and microwave links.

OPEN WATERS

Dodging the obstructive visa laws of some nation states is the first of many potential applications for seasteading. Scientists could use these artificial islands as independent labs where research in controversial areas, such as stem cell technologies, could proceed unhampered. They could also serve as sites for private clinics, where critically ill patients could



Left: TSI's Clubstead design is free-floating, protected against rough weather by large ballasts

receive life-saving treatments that are yet to make their way through the tortuous approval procedures of some nations.

Blueseed's entrepreneurial incubator will be a retrofitted second-hand cruise liner. This is the most inexpensive seastead design, but is perfectly adequate for the sheltered, calm waters off the California coast. For settlements further out to sea, somewhat more rugged structures will be needed (see 'How to build a city at sea', on p63).

"We are eager to see seasteads experiment with a wide variety of political ideas"



The most sophisticated are the so-called 'semi-submersibles'. These resemble offshore oil platforms, with buoyant pillars that extend far below the waterline but which aren't actually bedded in the ocean floor. TSI has produced a proof-of-concept design for such a seastead known as 'Clubstead' that would accommodate 200 residents and 70 staff.

Most seasteads of this size would have to be moored to the ocean floor using cables. In deep water, however, this is impractical and so-called



Architect Emerson Stepp's seasteading vision is called 'Oasis Of The Sea' – could it one day become a refuge for scientific research?

'dynamic positioning systems' would be employed instead. Here, latitude and longitude would be measured by Sat-Nav and thrusters would then correct for any drift.

Semi-submersible platform designs offer high levels of stability in rough seas. This is particularly true when the submerged part of the structure runs deep enough so that the platform's centre of gravity lies beneath the reach of the waves. "Semi submersibles offer the best tolerance to extreme environmental conditions," says George Petrie, previously Professor of Naval Architecture at New York's Webb Institute, and now TSI's Director of Engineering.

But even a structure such as this may not stand up to the most severe of ocean weather phenomena – hurricanes. A hurricane spits out destructive energy at the same rate as a 10-megaton nuclear detonation every 20 minutes. Faced with such a savage force, there's only one sensible course of action – get out the way. And this is something seasteads are quite capable of. Given

that hurricanes normally strike with several days' warning, there's plenty of time for a floating city to pull up its moorings, fire up the engines and relocate to calmer waters.

FISHY EXPORTS

As with any nation state, seasteads will import the goods they can't readily produce themselves – such as vegetables and meat – while exporting their own produce. This might include fish and other seafood that's farmed in giant nets slung beneath the structure – a practice known as 'aquaculture' – as well as minerals mined from the ocean bed. Perhaps even oil.

Fresh water will initially have to be imported, but advances in desalination may enable seasteaders to extract drinking water from ocean brine. One way to do this is by growing salt-loving plants, such as mangroves, in greenhouses – the plants could be irrigated with sea water, but then respire fresh water from their leaves, which can be captured.

But how would a seastead be powered? One solution is an emerging technology called Ocean Thermal Energy Conversion (OTEC). This is an energy-production system that works by exploiting the temperature difference between the ocean surface and the chilly depths to run a heat engine. The heat near the surface could, for instance, expand the gas in a piston and the cold contract it back again, creating a cycle of movement, the energy of which could be harnessed.

A useful by-product of the process is freshwater, which emerges in the form of water vapour given off by the engine. It's hoped seasteads will generate most of their own electricity, using OTEC together with solar, wind and tidal power.

In the future, there is no real limit to how big a seastead could get, so floating megacities are theoretically possible. Even skyscrapers are not out of the question, so long as the ►

HOW TO BUILD A CITY AT SEA

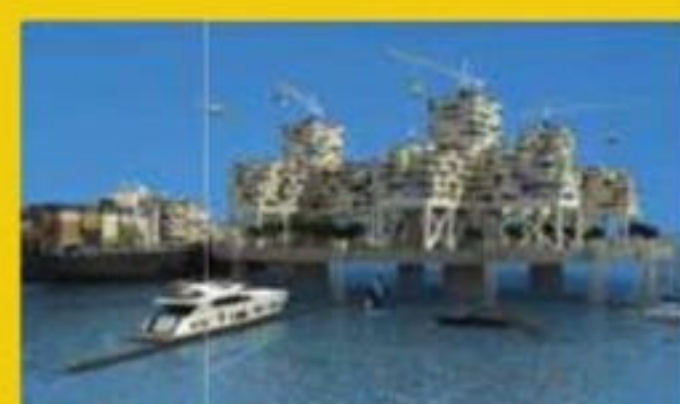
Three approaches to creating a community on the waves



1 CONVERT A SHIP

Ocean liners already have many of the facilities needed for people to live in comfort

for weeks on end and there are many second-hand cruise ships going cheap. Acquiring and refitting one of these vessels is the plan being adopted by seasteading start-up Blueseed.



2 FLOATING PONTOONS

Ships are optimised for moving through the water rather than staying

still, making them susceptible to rolling in choppy seas, causing seasickness. One alternative is flat-bottomed pontoons linked together. This scheme was investigated by the US Navy, but subsequently abandoned. The Seasteading Institute believes the improvements this design offers over ships, for relatively little extra cost, make it well worth revisiting.



3 SEMI-SUBMERSIBLES

This is just a fancy term for the design adopted by modern offshore oil rigs. The rig

is built upon pillars that sit beneath the waves. These are linked to hollow floats, or pontoons, that sit deep in the water. This configuration is extremely stable and resistant to rough weather. Weighted with ballast at the base, it swings back like a pendulum if tipped up. The Seasteading Institute has based its 'Clubstead' proof of concept study on a semi-submersible design.



FOR AND AGAINST FLOATING CITIES



CHARLIE DEIST
THE SEASTEADING INSTITUTE
STAFF WRITER

Will seasteading catch on?

One of the virtues of seasteading is that it is an incremental, bottom-up, doing-instead-of-talking movement. We do not need to win any elections, we just need to find a core group of committed pioneers – people who may not be sure that seasteading will work either, but believe it is worth a try. These kinds of people would rather convince through demonstration than through lengthy argument. If these individuals succeed, that is our answer.

How soon?

The full vision will likely take decades to realise, but single-purpose businesses such as Blueseed, operating on retrofitted ships or barges, could be coming within the next five years.

Would they be self-governing?

If you think of government as an industry, seasteads aim to reduce barriers to entry for producers, and provide ‘customers’, or citizens, with a wider variety of choices. We think future seasteads will make governments compete harder for citizens by providing better public services for their citizens at a lower cost.

ARNOLD KLING
THE CATO INSTITUTE THINK TANK
ADJUNCT SCHOLAR

Do you think seasteading is practical?

I am a sceptic. Cities are not easy to create in any setting, but when it comes to seasteading, the sea presents an additional challenge.

Seasteads wouldn't have to be city-sized?

No, but small settlements tend to be weak economically. Larger cities tend to produce more wealth.

Could the will to create better governments act as a driver to overcome these difficulties?

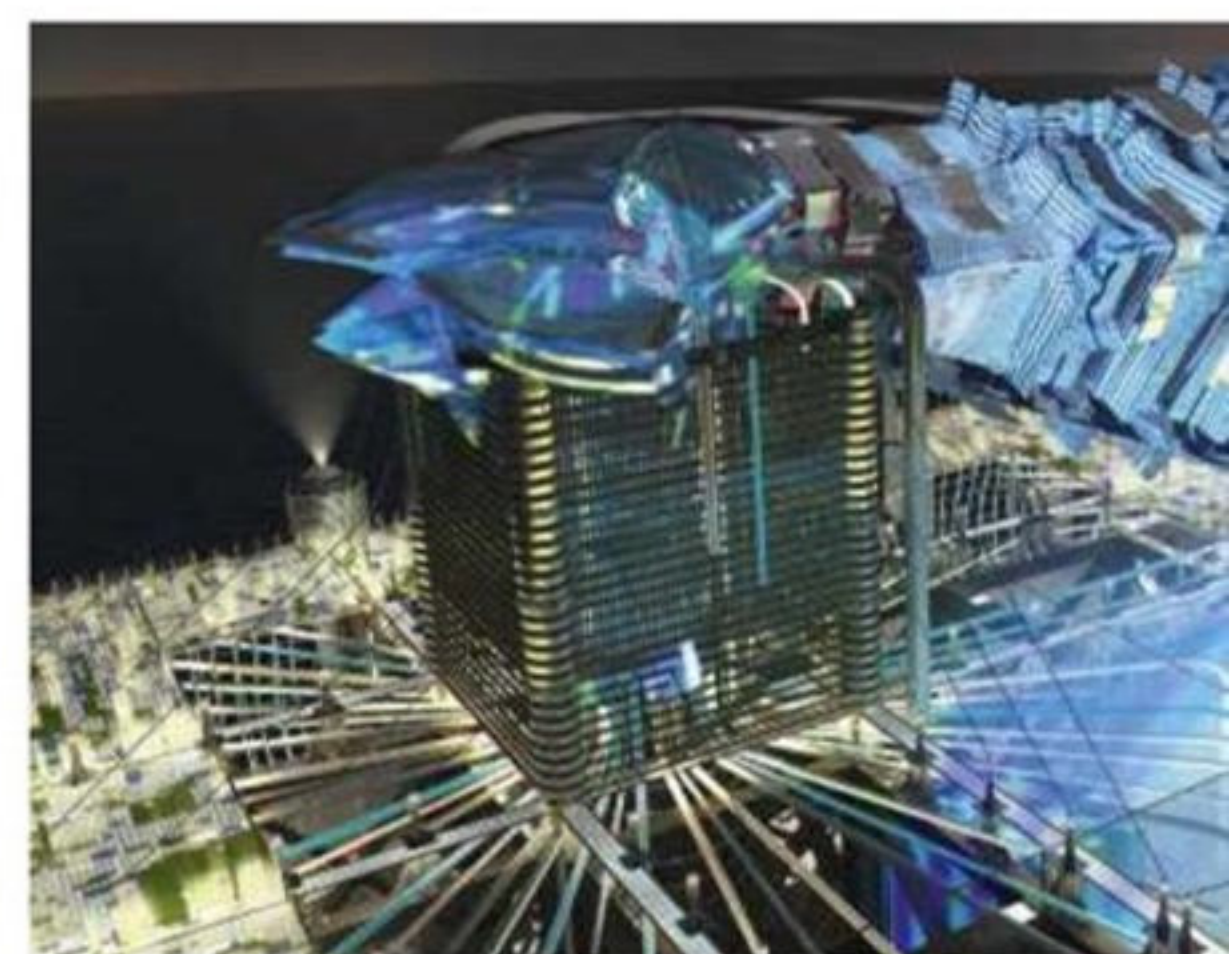
The seasteading idea is to create enough competition that burdensome governments get driven out of the market. It is a noble idea, but I am sceptical that it will work in practice. Cities require a lot of legal and regulatory infrastructure. The question is whether that infrastructure can be provided without the additional burden that governments impose.

And you think it can't?

It's a fundamental problem. But if you can't solve it on land, then I'm not convinced you can remedy it out at sea.



The cheapest way to start a seastead is to convert an old cruise liner, which Blueseed hopes to do by 2014



► floating platform is sufficiently stable. However, there is little motivation to build skyscrapers at sea. “People build skyscrapers because open land within a city is limited and expensive,” says Petrie. “At sea, there need not be any fixed boundaries to the city.”

As a floating city grows, so the inhabitants will require transport to get around. Petrie imagines a combination of walkways, escalators, bicycles and Segway-style scooters

*“At sea,
there need
not be
any fixed
boundaries
to the city”*



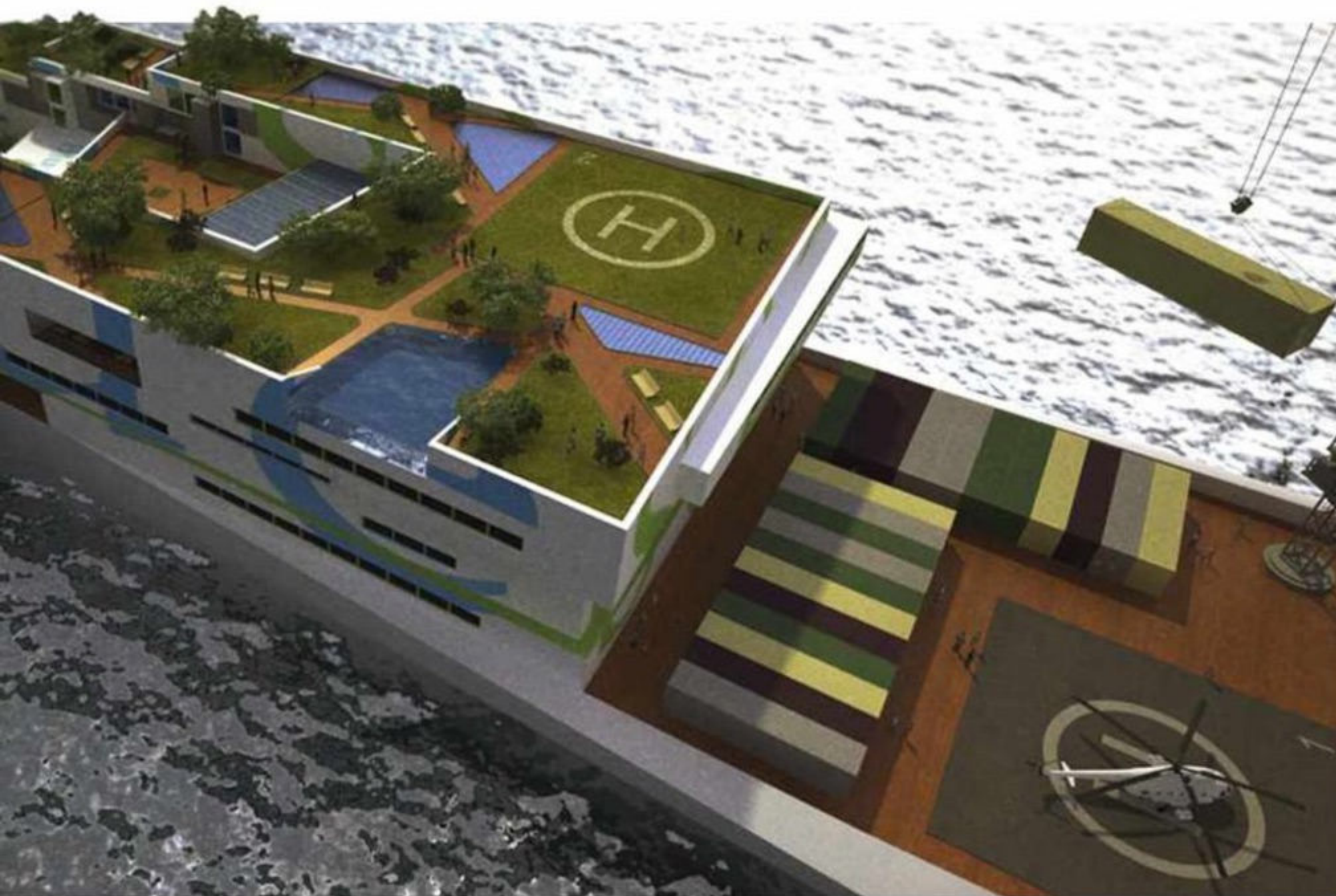
to start with. “Perhaps cities would be large enough to justify electric cars, but I would like to imagine an effective system of public transport,” he says.

ESCAPING NATURE

While moving around the city is unlikely to present a significant problem, relocating the city itself to escape an approaching hurricane would become problematic as it grows. So very large cities could

be equipped with a flotilla of escape craft in which the populace would literally ‘abandon city’ in the event of a major natural disaster. However, one benefit that a lack of mobility will bring is that inexpensive, yet high-bandwidth cables laid on the ocean floor can be used for internet and other communications rather than more costly laser and microwave links.

“Seasteading technologies will be very much less polluting than



Left: Seasteads of the future could take on radical designs, like this concept study of a floating city from Las Vegas-based artists Team 3DA

those typically used on land,” says Deist. “And bear in mind that resources will be in limited supply and so more expensive, which means there will be pressure on seasteaders to use less of everything.”

With its promise of new resources, living space, lifestyle and flexible government, seasteading offers new horizons and new opportunities to a human race that seems desperately in need of both. Mark Twain once wrote: “Buy land. They’ve stopped making

it.” He couldn’t possibly have foreseen the seasteading movement, one that its supporters now sum up with one simple motto: “Let a thousand nations bloom on the high seas.” ■

Dr Paul Parsons is a science writer and the author of *Science In 100 Key Breakthroughs*

FIND OUT MORE



Listen to an episode of the BBC World Service show *One Planet* with The Seasteading Institute’s Patri Friedman www.bbc.co.uk/programmes/p00g6zsf

www.blueseeds.co/
Watch a Blueseed video about its plans

www.seasteading.org
News and developments from the TSI

<http://youtu.be/gd-0keS6uDI>
Watch a video of Patri Friedman detailing the TSI’s ambitions

HOW DO I SIGN UP?

At the moment, there is only one commercial seasteading outfit with a definite timescale on which to begin operations. Blueseed wants to set up a seastead by early 2014 that’s far enough from the continental US that entrepreneurs won’t require work visas, yet close enough to Silicon Valley for business meetings.

Accommodation plus office space is priced between \$1,200 (£760) and \$3,000 (£1,900) per month for entrepreneurs. Blueseed is also offering a limited number of places to people who company founder Max Marty (pictured) describes as ‘enhancers’ – those who offer ‘enabling services’ including accountants, attorneys and IT specialists.

For everyone else who has maybe tried a cruise, and just fancies something a little longer term, there are other possibilities. “Seasteading is intended to be open to all,” says Charlie Deist of The Seasteading Institute (TSI). “There is currently no formal process for signing up, but there are a number of ways for people to situate themselves to be seasteading in the near future.”

Deist suggests joining the Institute and attending its annual conference to make connections. There are also several programmes run by the Institute that

Blueseeds founder Max Marty



DESTINATION SOLAR SYSTEM

Half a century after Mariner 2 first encountered Venus, Govert Schilling takes you on a tour to five destinations scientists would love to explore

ATION SYSTEM



What lies under the surface of Mars? The Seven Sisters caverns could provide shelter for future astronauts, shielding them from the radiation-blasted surface

The exploration of the Solar System turns 50 this month. On 27 August 1962, NASA launched Mariner 2 – the very first space probe to travel to another planet. During its interplanetary journey, the tiny craft discovered the solar wind (the continuous flow of charged particles emanating from the Sun) and, when it flew by Venus in mid-December 1962, it revealed the planet's incredible surface temperature of 460°C. For the first time in history, mankind had physically reached out to an alien world.

Today, space exploration is no longer a novelty. Each of the eight planets in the Solar System has been studied at close quarters by spacecraft. Landers have touched down on Venus, Mars and Saturn's

biggest moon, Titan. We've sampled comets, asteroids and the atmosphere of Jupiter, and it's almost impossible to keep up with the avalanche of images and data from space probes like Messenger (orbiting Mercury) and Cassini, which has been touring Saturn and its moons since 2004.

But where haven't we been, and why should we go there? On the following pages we take a trip to five unexplored places in the Solar System, from the mysterious face of Mercury, the nearest planet to the Sun, to an icy body in the outer limits. Sending missions to some of the exotic locations on the following pages will further our understanding not just of them, but also of our own planet's atmosphere and geology. Our journey of exploration has only just begun. ►

CHAO MENG-FU

- What: crater
- Location: Mercury, south polar region

A colossal crater near Mercury's south pole has a permanently dark floor that's probably covered with ice

You'd be forgiven for thinking that ice on Mercury was impossible. Mercury is, after all, the innermost planet in the Solar System, with a surface cooked by the Sun to hundreds of degrees. Close to its poles, however, it's a different story. The Sun is always near the horizon, and some craters there are deep enough to have cold, permanently shadowed floors. Radar observations suggest the existence of ice in these planetary cold traps.

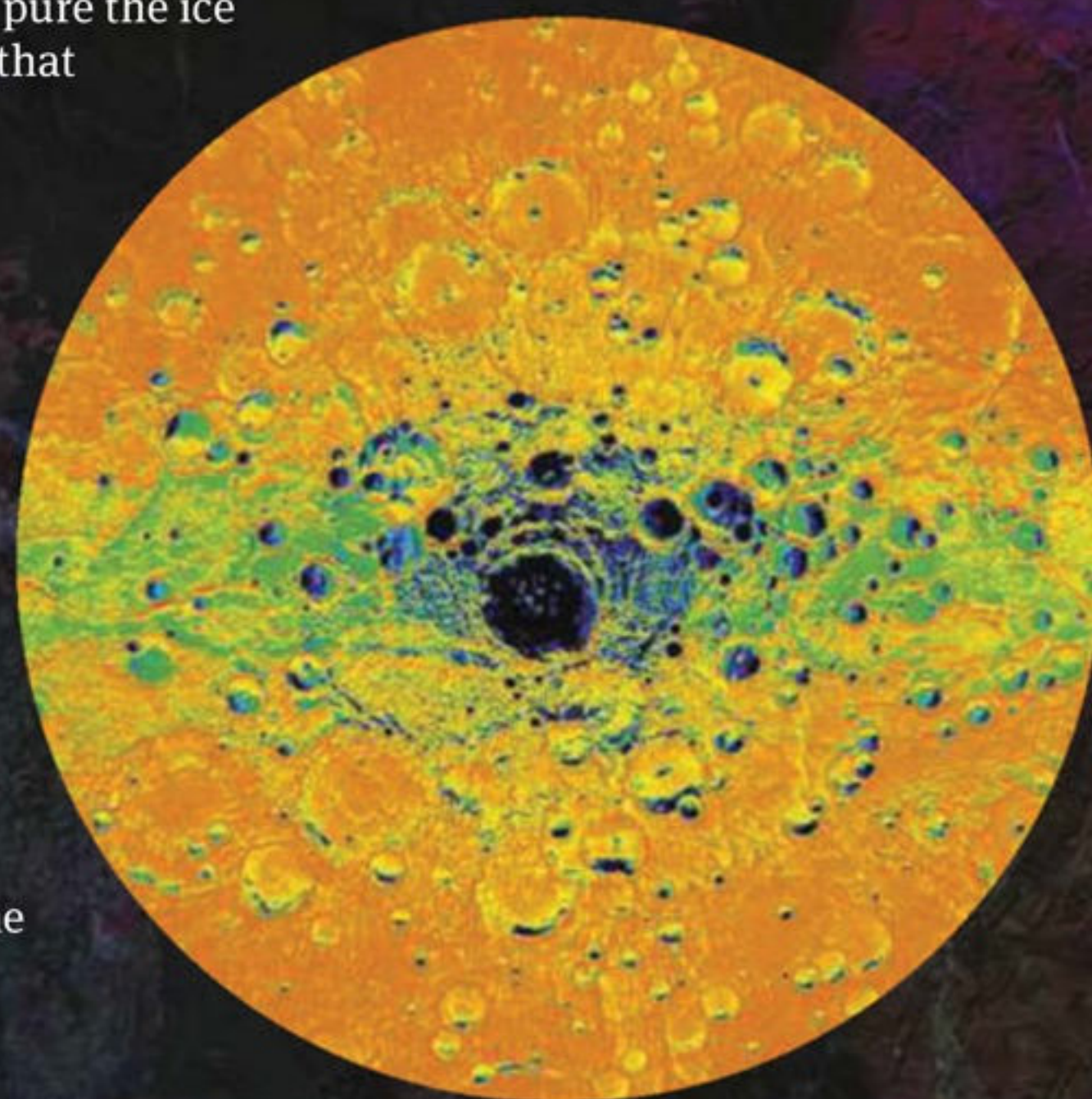
Descending into the 167km-wide crater Chao Meng-Fu – named after a 13th-Century Chinese painter and calligrapher – would be a dangerous adventure. Mercury has no atmosphere to scatter sunlight down into the crater floor, so the only light comes from the parts of the crater's rim that bask in the fiery rays of the invisible, low-altitude Sun. These narrow, blindingly bright patches of rock would appear perched between a star-studded blackness above and an equally black but starless void below.

The floor of the crater is an appealing target for exploration, says Dr Nancy Chabot of the Applied Physics Laboratory at Johns Hopkins University in Maryland, US. "Our thermal models predict Chao Meng-Fu is cold enough to contain vast exposed ice fields. It might even be possible to go ice skating there," she says.

Using radar altimetry data from NASA's Messenger spacecraft, Chabot's team has determined which crater floors are permanently shadowed. Their map reveals a perfect match with ground-based radar observations that hint at the presence of ice. "Messenger's neutron spectrometer is now trying to detect the signature of hydrogen atoms in the ice," Chabot explains. "But it's a tricky measurement."

Going to Chao Meng-Fu would enable scientists to work out how old and how pure the ice is. The leading hypothesis is that it's been delivered over the aeons by impacting comets. Ice from comets would instantly evaporate on most of Mercury's hot surface but it would remain deep-frozen on the dark polar crater floors.

Chabot says this will also help us understand the origin of our own planet. "Learning more about how and when water was brought to Mercury will shed light on how Earth acquired its oceans early in the history of the Solar System."



Explorers of Mercury's Chao Meng-Fu crater would descend into total darkness as the surface above is scorched by the Sun. Inset: a radar image from the Messenger probe shows the massive crater as the dark central area

SEVEN SISTERS

- What: subterranean caverns
- Location: Arsia Mons, Mars

Underground caverns on the side of a Martian volcano could contain alien life or house future astronauts

You're way up on the slope of Arsia Mons, one of the giant shield volcanoes on Mars. Your face helmet is sandblasted by fine dust, blown across the stark landscape by strong winds. Wisps of cirrus cloud drift in the dark indigo sky. Before you is a circular hole in the ground, some 200m across. No one knows what's inside. Would you dare to enter?

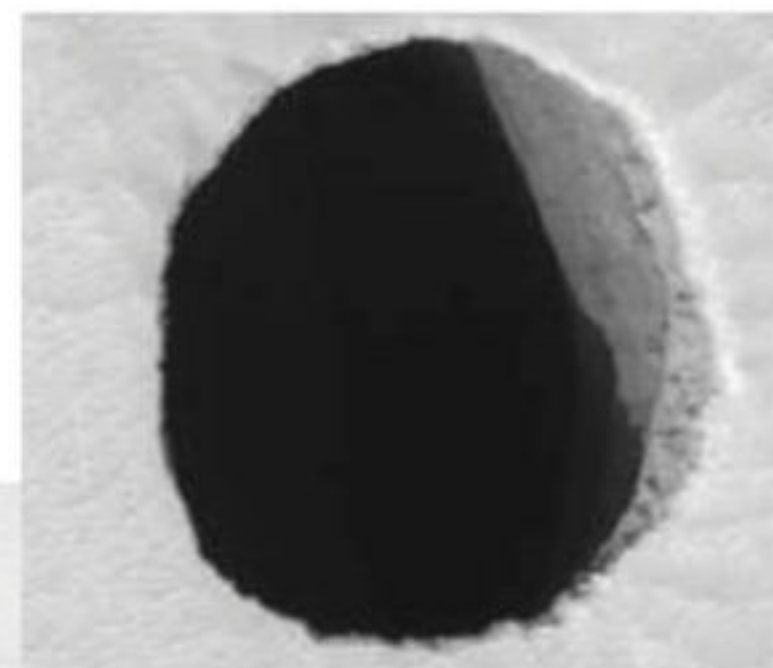
Well, scientists would love to, but might prefer to send robotic rovers in first. After all, they have no clue about the depth of the mysterious caves on Mars. They might be relatively shallow and partially collapsed lava tubes. But then again, the dark openings could also be skylights that provide access to extensive networks of subterranean caverns.

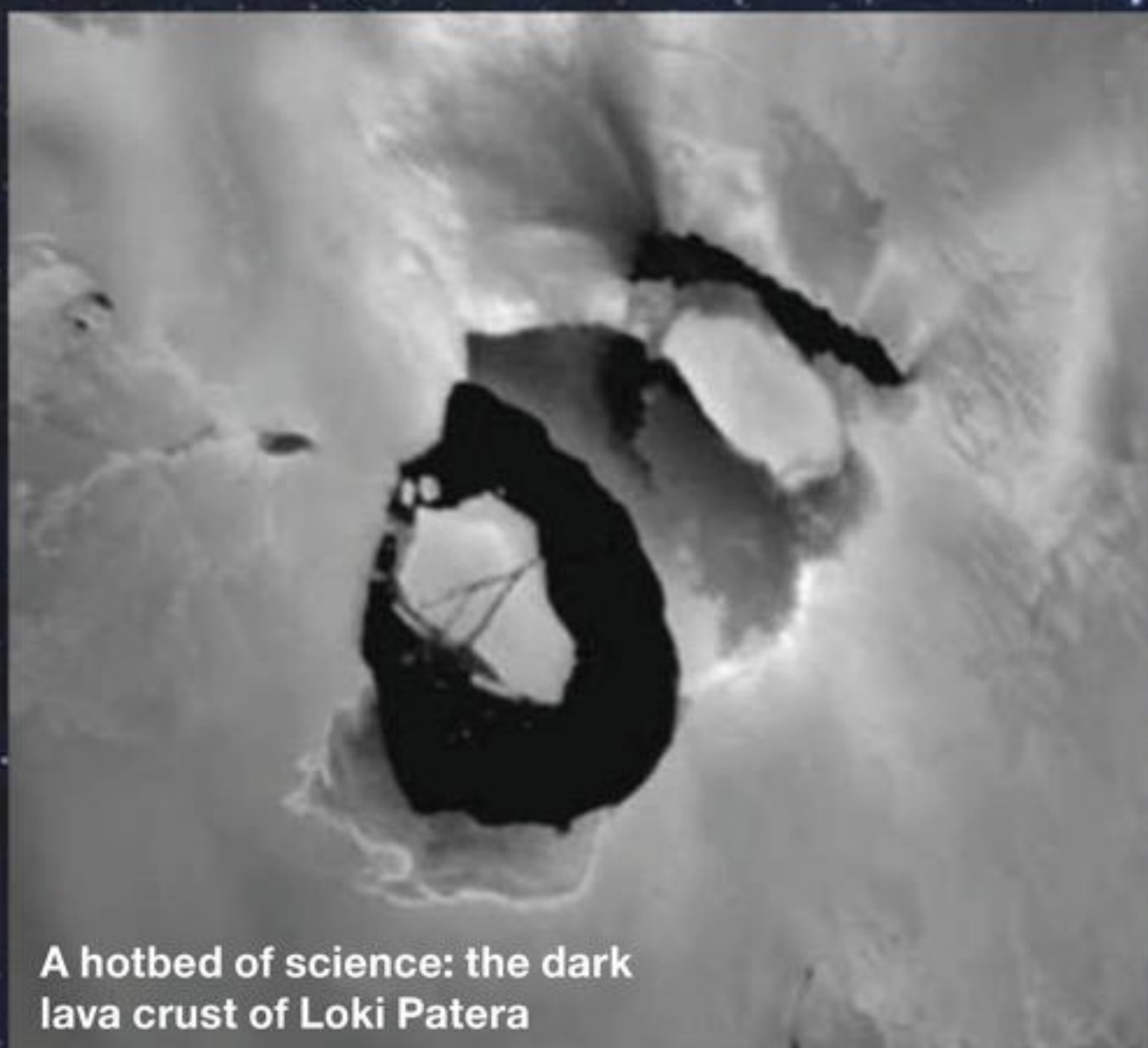
The first Martian caves were found in 2007, by Glen Cushing of the US Geological Survey. Dubbed the Seven Sisters, they were given the nicknames Abby, Annie, Chloe, Dena, Jeanne, Nikki and Wendy. During the day, they're colder than their surroundings; at night they're warmer – just the behaviour you expect for underground caves.

Over the years, more caves have been found, one by a group of Californian middle school students. According to Natalie Cabrol of NASA's Ames Research Center, the Martian caves would be great places to explore. Why? Because their interiors are shielded from the harsh conditions at the Martian surface, which is battered by ultraviolet sunlight and cosmic rays.

The Seven Sisters might harbour extraterrestrial microbes, or at least provide a natural shelter for future human explorers.

Right: sunlight catches the eastern wall of a Martian cavern – a pit on the slopes of Arsia Mons, seen below in this image from NASA's Mars Reconnaissance Orbiter





A hotbed of science: the dark lava crust of Loki Patera

LOKI PATERA

- What: lava lake
- Location: Io, a moon of Jupiter

A vast lava lake on a distant moon could reveal the secrets of Earth's early geology

Located on Io, the innermost of Jupiter's four Galilean moons, Loki Patera is the Solar System's largest lava lake. Almost as big as Northern Ireland, it's usually covered with a lava crust. But every two years or so, the crust is replaced by fresh lava reaching up to 700°C.

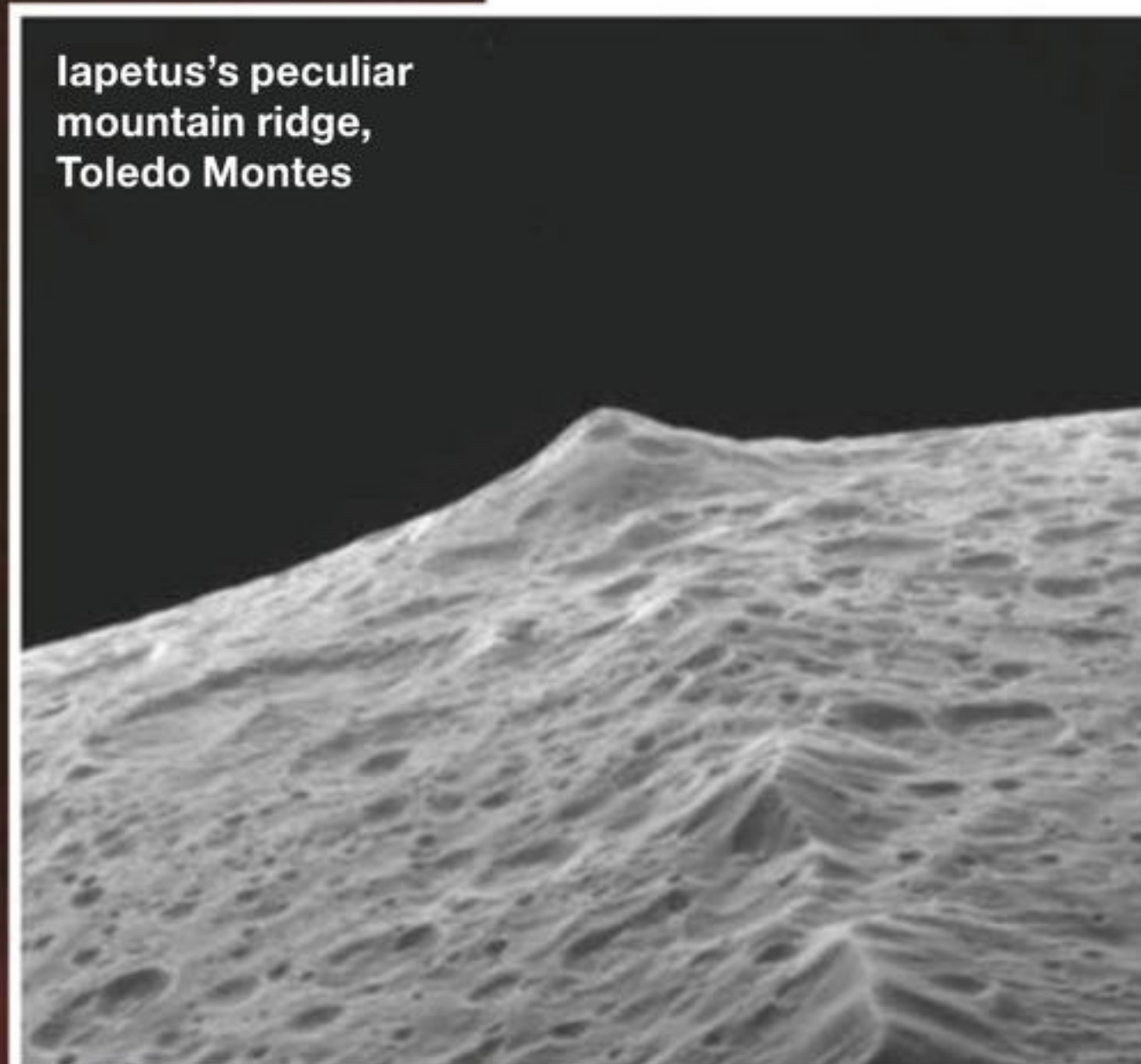
Imagine standing on the rim of Loki Patera, looking out at an expanse of incandescent, bubbling molten rock that stretches beyond the horizon. The heat is unbearable, and everything smells of

sulphur. Meanwhile, the gas giant Jupiter looms above, the size of 40 full Moons in the sky. What a view! But if you're planning a visit, be very wary of lava reaching the surface. "Landing would be extremely hazardous unless you could time the landing between resurfacing events," warns Dr John Spencer of the Southwest Research Institute in Colorado, an expert on Io.

Scientists know that Io's incredible volcanic activity is powered by giant Jupiter's tidal energy, which squeezes the rocky interior, but Loki Patera still holds many secrets. "We'd love to measure the composition of the lava, stick around long enough to see the crust being replaced, and measure the seismic activity to learn about the interior," says Spencer. In particular, he adds, studying Loki might tell scientists how volcanoes worked on the early Earth, when the heat flow was much larger – more like that of Io.

The view across the lake of lava that is Loki Patera would be spectacular, but the extreme temperatures would make it a hostile place to visit

Iapetus's peculiar
mountain ridge,
Toledo Montes



TOLEDO MONTES

- What: mountain ridge
- Location: Iapetus, a moon of Saturn

How this massive mountain range formed on Saturn's moon Iapetus remains a mystery

Higher than Mount Everest, Toledo Montes is a 1,300km-long mountain ridge on Saturn's moon Iapetus. "Nobody ever predicted something like this; I was stunned when I first saw it," exclaims planetary scientist Dr Andrew Dombard of the University of Illinois in Chicago.

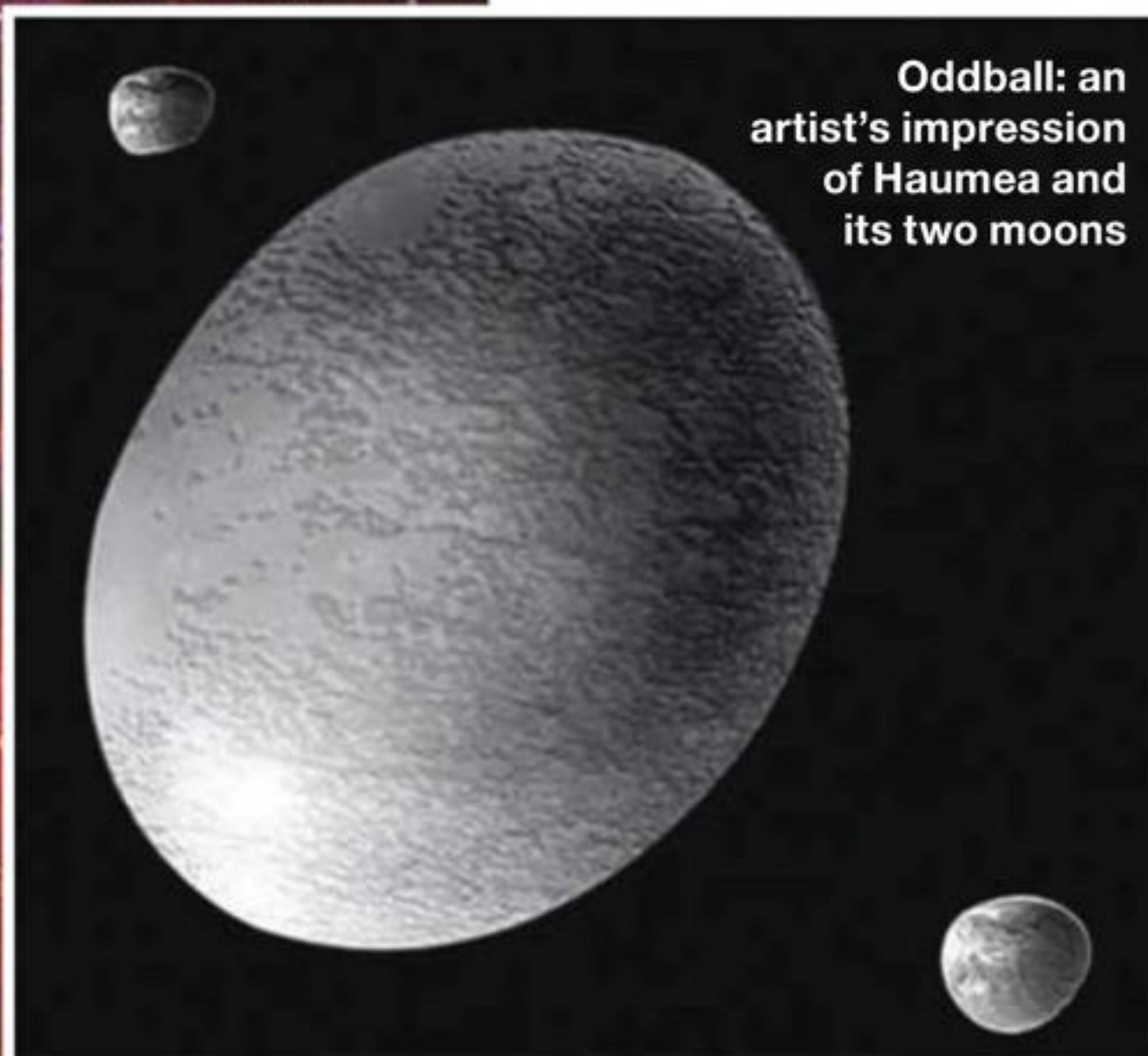
Toledo Montes stretches across one-third of the equator – over twice the length of the Pyrenees mountains – and gives Iapetus an eerie, walnut-like appearance. Some scientists think the ridge is a tectonic feature, caused by Iapetus's fast rotation in the distant past, although Dombard believes the ridge formed when a sub-satellite of

Iapetus was shattered and spilled icy debris on to the surface.

Going to Iapetus would reveal the composition, age and porosity of Toledo Montes. If Dombard is right, there might be a measurable difference in composition between the ridge and the rest of the moon. "The origin of the mountain ridge is not a solved problem by any means," Dombard says.

Given that Iapetus's surface gravity is 40 times less than Earth's, a hike to the tallest peaks of the mountain ridge would be an easy stroll, made all the more enjoyable because of the spectacular view of Saturn and its rings.

Oddball: an
artist's impression
of Haumea and
its two moons



HAUMEA

- What: dwarf planet
- Location: the Kuiper Belt

An elongated, eccentric dwarf planet that orbits beyond Neptune

At -220°C , Haumea is one of the coldest celestial bodies in the Solar System. Twice as long as it is wide, a day on this oval rock would last less than four hours. Measuring 1,960km along its longest axis – almost twice as wide as Pluto – Haumea is one of the largest inhabitants of the Kuiper Belt, a region of space beyond Neptune. The Kuiper Belt consists of asteroid-like objects, the majority of which are made up of 'ices' of methane, ammonia and water. Haumea is different in that it's composed mainly of dense rock, with a thin shell of ice and a large, reddish, mineral-rich area on its surface.

Scientists believe Haumea was much larger in the distant past, but lost most of its ice mantle layer following a giant collision in the outer Solar System. In fact, a team led by Mike Brown of the California Institute of Technology in California discovered a whole family of smaller Kuiper Belt objects that share physical and orbital properties with Haumea – most likely debris from the collision.

Haumea even has two moons: fragments of debris – named Hi'iaka and Namaka – revolve around the dwarf planet. A trip to Haumea would undoubtedly offer some fascinating insights into the violent early youth of the Solar System. ■

*Govert Schilling is
the author of Atlas Of
Astronomical Discoveries
and has an asteroid named
after him, '10986 Govert'*

FIND OUT MORE

<http://bbc.in/bbcsolar>
BBC – Explore the Solar System



Watch clips from *Wonders
Of The Solar System*
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Q&A

Your questions answered

How long after the Big Bang did life start?	p74
Do animals see the same colours as us?	p75
How many dinosaurs roamed the world?	p77
How does a self-cooling can work?	p79



Seagulls will fearlessly defend their nests, with vomit and then a fearless dive bomb

Are seagulls becoming more aggressive?

LIAM JOHNSON, PLYMOUTH

No. They have always been very aggressive, particularly when defending nesting sites. What they are becoming is more *numerous*. In the wild, herring gulls might only raise one chick to maturity for every 10 breeding pairs per year. The rest are lost to predation from other seabirds,

birds of prey and seals. In contrast, gulls that nest in cities have more secure nests and much greater access to food, mostly from rubbish bins and landfill sites. Street lighting also allows birds to forage at night. For example, Bristol now has more than 2,000 breeding pairs of gulls, each

of which can raise two or three chicks a year. The increased population density means that humans are much more likely to encroach on nesting territory. Seagulls will actively defecate and vomit on anyone they perceive as a threat, before resorting to dive bombing. LV

500

trillion watts was the power of the most intense laser shot ever fired, as part of experiments into fusion energy at the National Ignition Facility in the US on 5 July.

Send us your questions

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The experts



SUSAN BLACKMORE
Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*



DR ALASTAIR GUNN
Alastair is a radio astronomer at Jodrell Bank Centre for Astrophysics



ROBERT MATTHEWS
After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University



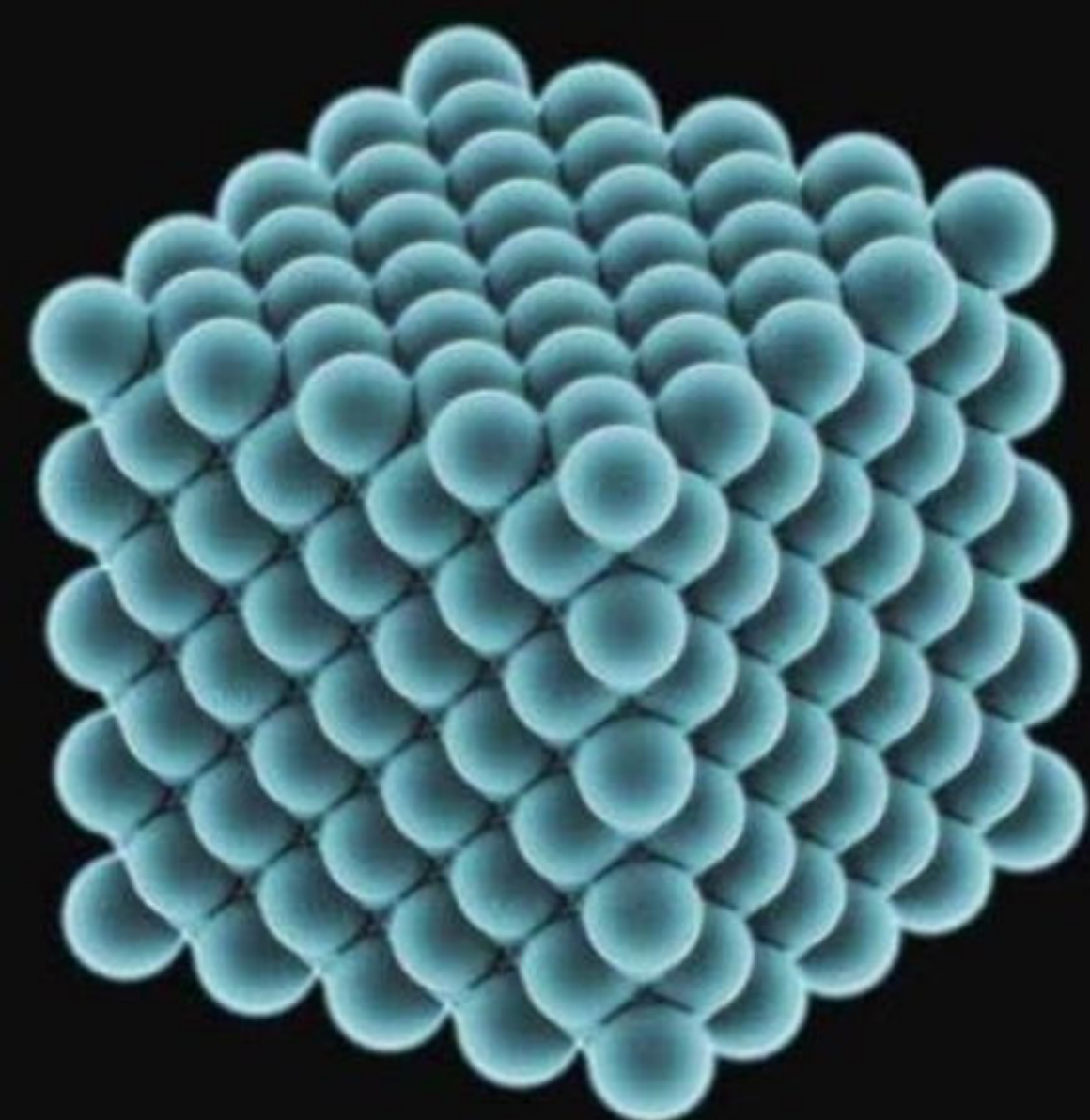
GARETH MITCHELL
Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* on the BBC World Service



LUIS VILLAZON
Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach the Ground*

What makes matter 'solid'?

FRANK RICHTER, SOUTH AFRICA



The atomic structure of diamond – one of the hardest materials known

We say something is solid if it's hard to pass anything through it, such as a knife. It means that the atoms making up a solid are tightly bonded together. Just how tightly depends on external conditions: a combination of low temperature and high pressure will persuade even the most reluctant atoms – like those of helium – to form a solid. On the other hand, given a high enough temperature, even the most formidable solids will disintegrate. **RM**

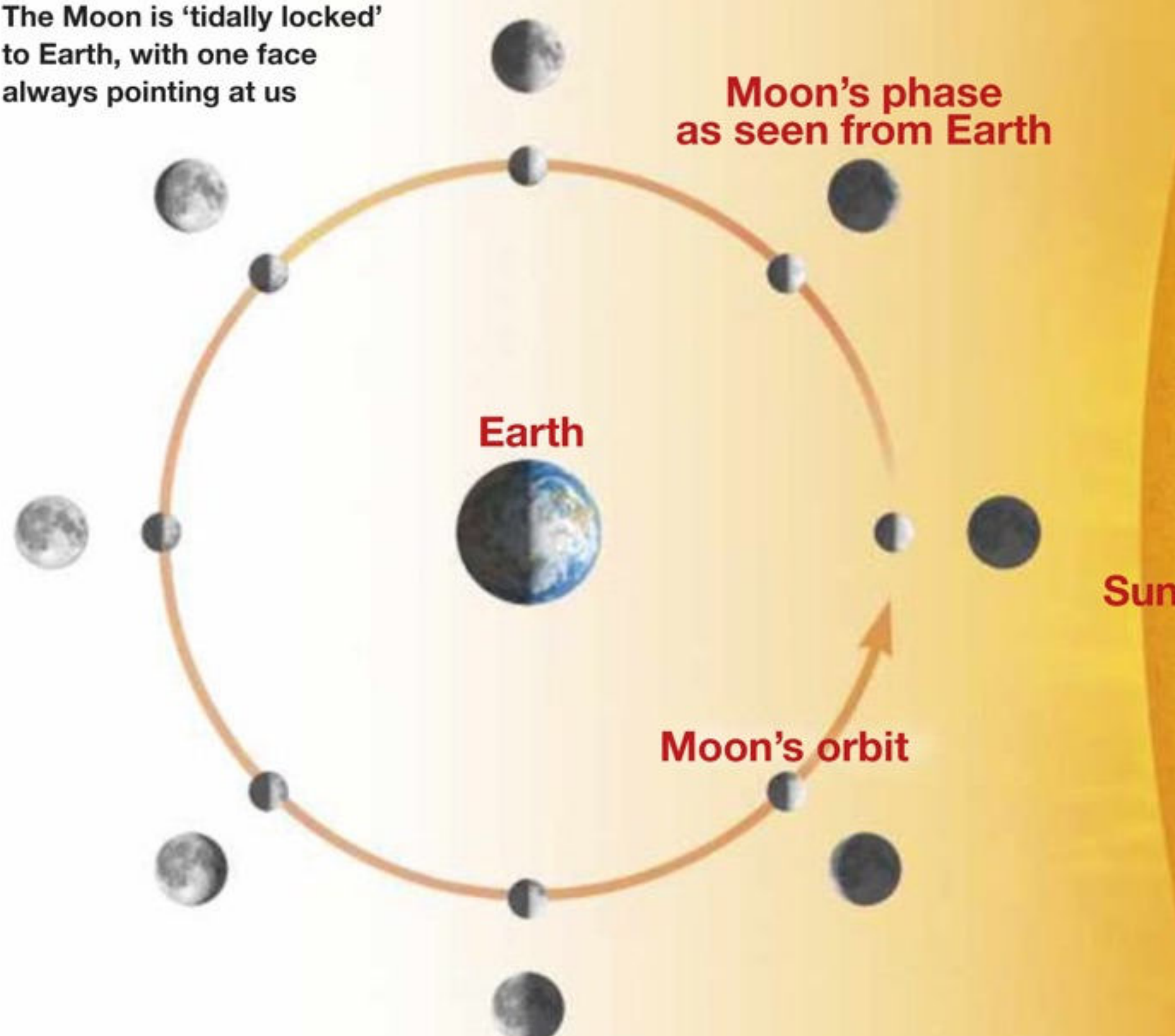
Why can we only see one side of the Moon?

GREG GANTER, CALIFORNIA

The time taken for the Moon to spin on its axis is almost exactly the same as the time it takes to orbit the Earth. Hence, the Moon always keeps the same side pointing our way. This is not a coincidence. Over billions of years, the Earth's gravity has forced the Moon to spin synchronously with its orbit.

However, things are a bit more complicated than that. Viewed from Earth, the Moon appears to rock slowly backwards and forwards so that we see a slightly different face throughout the lunar month. There are two main reasons for this. First, the Moon's orbit around Earth is elliptical not circular so its rotation is sometimes ahead, and sometimes behind, its orbital motion. And second, the Moon's rotation axis is not at right angles to its orbit around the Earth so we can sometimes see 'over' or 'under' its poles. Over time this means we actually get to see about 59 per cent of the Moon's surface. **AG**

The Moon is 'tidally locked' to Earth, with one face always pointing at us



How do our eyes move together?

LUKE AZZOPARDI, MALTA

Our eyes move in the same direction all the time as we glance around making quick eye movements called saccades, or when we track moving objects. However, they also move in the opposite direction when we change from looking at something in the distance to something close. In this case they both point further inwards, or converge. Looking further away they both move outwards or diverge. All these movements are controlled by the six extraocular muscles that connect the eyes to the surrounding skull. They are initiated either by the frontal eye fields, in the brain's prefrontal cortex, or automatically by a subcortical structure called the superior colliculus. **SB**



QUESTION OF THE MONTH

What's the soonest life could have evolved after the Big Bang?

RICHARD BULL, BY EMAIL

That depends on what you mean by 'life', but it's reasonable to say that the absolute minimum requirement is the existence of molecules made from relatively heavy elements like carbon, oxygen and nitrogen. In that case, we can certainly exclude the existence of life for several hundred million years after the Big Bang. That's how long it took for the appearance of the first stars, the thermonuclear reactions of which are needed to 'cook' the hydrogen and helium formed in the Big Bang into heavier elements. These first-generation stars are believed to have been far more massive than our Sun, and to have burned brighter but for a much shorter period of time – perhaps just a few million years before exploding. So that puts the earliest possible date for the emergence of life at around several hundred million years after the Big Bang. RM

The first life would only have emerged once heavy elements were produced by stars

RICHARD WINS A COPY OF **MEGACATASTROPHES** BY DAVID DARLING (ONEWORLD, £11.99)



Do animals perceive time?

JASON GOODLEY, LINCOLNSHIRE

All but the simplest animals will change their behaviour based on things that have happened to them in the past, and they are sensitive to the time of day and the season. But that's not the same thing as an episodic sense of time – the ability to order the events of their past on an internal calendar. Research with rats, pigeons and apes has shown that animals can remember how long ago an event occurred, but not when. It's as if they are simply tracking the strength of a fading memory, rather than placing it on an internal calendar.

The reason for this may be that an autobiographical sense of the past depends on having language and number skills to create a calendar framework. Research has shown that

even humans don't have much of an episodic memory before the age of four. Another possibility may be that their 'time horizon' is much nearer than ours. Give monkeys

a choice between two bananas or one, they choose two. But between five bananas and 10 they don't care. Tomorrow they will be hungry again, but this future self doesn't seem to exist in their minds. LV

Monkeys think no more than two bananas into the future



How are nutritional values determined?

PAUL HOSIER, SPAIN

Calorie content is measured in a device called a bomb calorimeter. You burn a sample in a sealed container of pure oxygen immersed in water, and measure how much the water temperature rises.

For protein measurement, the Kjeldahl method uses sulphuric acid to react with the nitrogen in protein and measures how much ammonia is produced. Fats can be measured by dissolving them out in a solvent such as hexane. LV

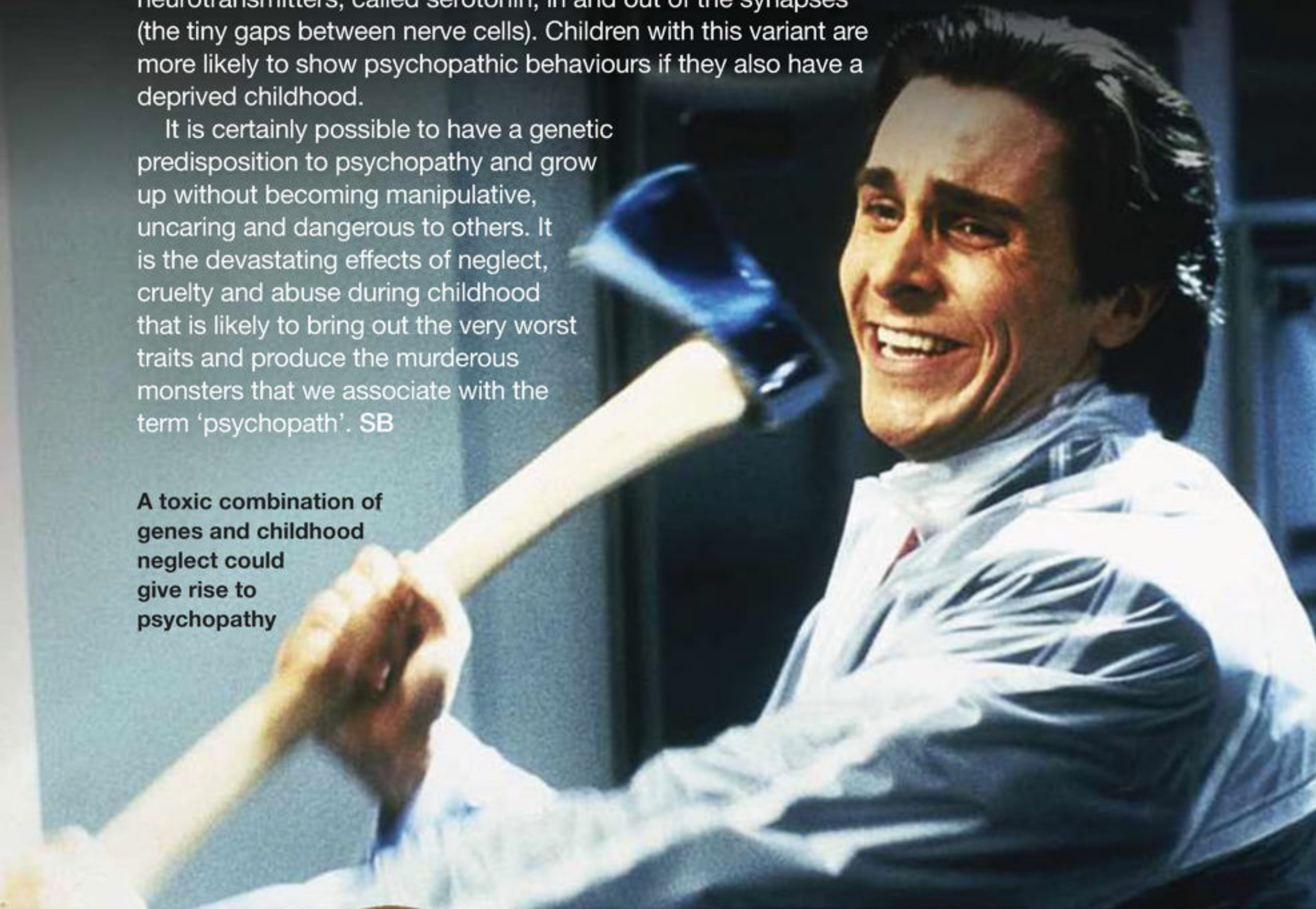
What causes psychopathy?

CLAIRE RIDDLE, LANCASHIRE

Like so many other conditions it's a mixture of genetics and environment. From twin studies we know that the heritability of psychopathic traits may be as much as 50 per cent and that the characteristic callousness, antisocial behaviour and lack of empathy can be detected as early as 9 or 10 years of age. One of the genes responsible has even been identified. It is a variant of a gene involved in transporting one of the brain's neurotransmitters, called serotonin, in and out of the synapses (the tiny gaps between nerve cells). Children with this variant are more likely to show psychopathic behaviours if they also have a deprived childhood.

It is certainly possible to have a genetic predisposition to psychopathy and grow up without becoming manipulative, uncaring and dangerous to others. It is the devastating effects of neglect, cruelty and abuse during childhood that is likely to bring out the very worst traits and produce the murderous monsters that we associate with the term 'psychopath'. **SB**

A toxic combination of genes and childhood neglect could give rise to psychopathy



Do other animals see colour the way we do?

ANIS BAYTAMOUNY, BY EMAIL

Colour vision in animals can be investigated by training them to find a reward associated with one colour rather than another; only if they can see the difference can they learn the task.

From such experiments we know that most mammals have limited colour vision and are usually red-green colour blind, including dogs, cats, and most farm animals. Some monkeys and all apes have vision similar to ours; they are trichromats, meaning that they have three types of cone (the colour receptors in the eye). Many other mammals are dichromats but nocturnal mammals have little or no colour vision.

Many birds, fish, reptiles and amphibians, as well as some invertebrates, have more than three cone types meaning they can distinguish more colours than we can. The most complex colour vision systems are found in crustaceans, such as the mantis shrimp, which is thought to have 12 different receptor types. It's impossible for us, with just three, to even imagine the colours it sees. **SB**



QUICKFIRE

Do square galaxies exist?

SIMON HILL, LONDON

No, there are no square galaxies. Galaxies are generally flattened discs, or are elliptical or spherical in shape. About a quarter of galaxies are 'irregular', in that they have no discernible structure and appear chaotic. These are probably formed by gravitational interactions between normal galaxies. However, no one has yet found an irregular galaxy that by chance appears square! **AG**

What is anti-noise?

ANDREW EVERSETT, DEVON

Anti-noise is the opposite of a particular sound. To produce it, sound is converted to an electrical signal. This is processed so that wave peaks become troughs and vice versa. The resulting signal is out of phase with the original. When the anti-noise signal is converted back into sound, each peak of the noise is cancelled out by the trough of the anti-noise, reducing the overall volume. **GM**

Is it possible to make your computer virus-proof?

NOAH POWELL, TAUNTON

Yes. Avoid connecting to the internet or another computer and never use an external drive. That answer is not quite as facetious as it sounds. As soon as your machine is networked, it is vulnerable. Whether through trojan horses, worms or rootkits, the most robust system can potentially be breached. Worms like Stuxnet in 2010 proved that even the supposedly secure Bushehr nuclear plant in Iran was vulnerable. **GM**

Why are flies attracted to lights?

ADAM DOOLEY, MANCHESTER

Flies navigate using the stars and Moon and so they may try to use other lights for guidance and get confused. Another possible reason is that the area just outside a light appears darker, so nocturnal flies head towards this dark patch and veer away from a light at the last second. **SB**



TOP TEN COUNTRIES BY AREA (IN MILLIONS OF KM²)

1. Russia

17.098

It is spread across nine time zones.

Population: 143 million



2. Canada

9.985

Without its lakes and rivers, it

would rank fourth. Population: 34 million



3. USA

9.629

It ranks high because 15 per cent

of it is Alaska. Population: 313 million



4. China

9.597

It has more people than any

other country. Population: 1.3 billion



5. Brazil

8.515

The largest country by area in the

southern hemisphere. Population: 192 million



6. Australia

7.692

Home to the Outback, one of the harshest

climates in the world. Population: 23 million



7. India

3.166

It's home to the second highest

number of people. Population: 1.2 billion



8. Argentina

2.767

The largest Spanish-speaking

country by area. Population: 40 million



9. Kazakhstan

2.725

The largest land-locked

country by area. Population: 16 million



10. Sudan

2.506

The largest country by area in Africa.

Population: 40 million



Book yourself
a ticket to the
future with
tank space in a
cryonics institute

How many people have been cryogenically frozen?

LEN WHEELER, GLASGOW

Cryonics, freezing people in the hope that they might one day be brought back to life once technology has made it possible, is only legal once a person has been legally declared dead. So technically, it's only corpses that are frozen, not people. The Alcor Life Extension Foundation currently has 111 frozen bodies and heads in storage. But human embryos are routinely frozen during in vitro fertilisation; 7,200 in 2010 in the UK alone. **LV**

Honey Bees latch on to a Grape
Hyacinth; the flowers make it
easy for insects to get a grip



How do bees grip onto flowers?

SAM O'BRIEN, SHEFFIELD

Each one of a bee's feet comes equipped with a suction pad, called an arolium, and a tarsal claw. But flowers depend on bees for pollination, so it is in their evolutionary interest to make it easy for bees to hold on, even on windy days. About 80 per cent of flowering plants have special cone-shaped cells on their petals. These may have initially evolved to focus light on to the petal, to make the flower appear a brighter colour. But their size (about 0.02mm across) and spacing, also creates a Velcro-like material that makes it particularly easy for bees to wedge their claws in place. Flowers with dense clusters of petals like roses don't need very big cone cells but on wide, open flowers like petunias, the cone cells are so long the flower almost feels velvety. **LV**

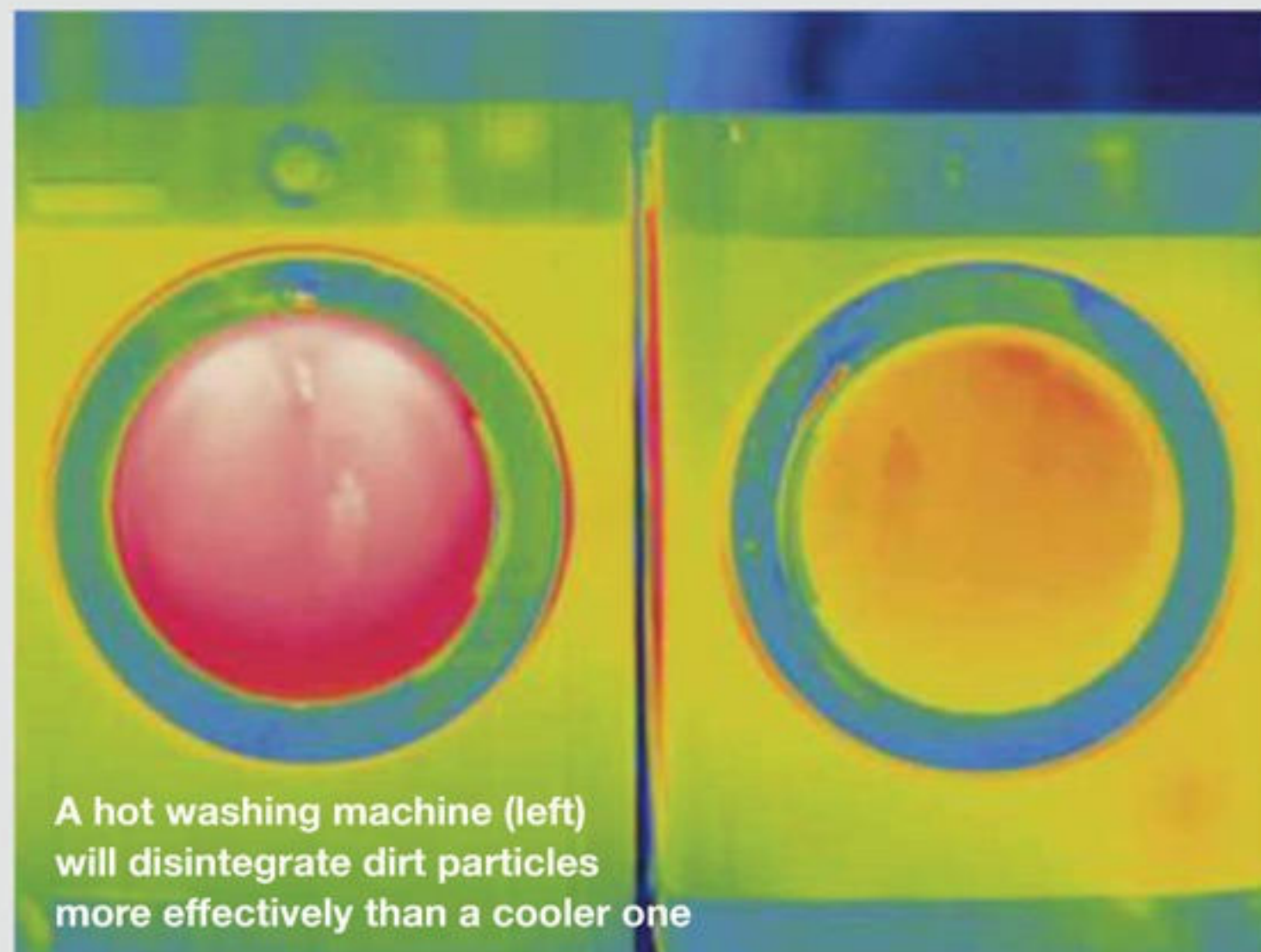
If you could travel close to the Orion Nebula, what colours would you see?

MATT BOYLE, YORK

You wouldn't see much colour at all. The nebula would appear brighter only because it would appear bigger. However, its 'surface brightness' (the amount of light per unit area) would not have changed. So it would appear just as dim as through a large telescope here on Earth.

Unfortunately, at such low light levels, the eye has great difficulty discerning colours. However, it may be possible to see a faint hint of colour. Your eyes may detect green (due to hydrogen gas), blue (oxygen), red (nitrogen) and violet (helium). These colours would certainly not be as impressive as those seen in the beautiful images taken with instruments such as the Hubble Space Telescope. To get those images astronomers take extremely long exposures, use super-sensitive colour-detecting devices, and often enhance the colours artificially. **AG**

The Orion Nebula may be a bloom of colour in images, but even getting up close would not deliver the same results with the naked eye



Why is hot water better for washing than cold?

FERGAL O'BRIEN, DUBLIN

Most solids dissolve better at higher temperatures. This is because heating a particle of dirt increases the amount of vibration in its molecules, loosening it up. It also means that the water molecules are moving faster, so they have more chance to knock dirt off the surface and into solution.

Detergent and soap also both work better at higher temperatures because the reaction by which they attach to dirt particles requires energy. This is only true up to a point, however; biological detergents contain enzymes that are destroyed by temperatures much above 40°C. **LV**



The population of dinosaurs could have numbered 20,000,000

At their peak, how many dinosaurs roamed Earth?

GRAHAM ROE, LANCASHIRE

There are around a thousand different genera of dinosaurs known. We can't directly measure the size of populations because we don't know what percentage of individuals are preserved in the fossil record. Twenty million bison roamed America in the 18th Century and dinosaurs, being egg layers, could have reproduced faster. Assuming that the availability of plants was the limiting factor, large dinosaurs probably reached comparable population sizes in the Jurassic, 60 million years ago. **LV**



Look but
don't touch!

Can you lose your arm reaching into a spinning drier?

JUNE HOLLIS, BATH

Spin-driers extract water from wet clothes via the acceleration created in the small drum spinning at over 2,500rpm. The resulting accelerations are incredible, which can exceed 1,400 times that due to gravity. Small wonder, then, that spin-driers have safety interlocks to prevent people reaching in. But the risk only comes from actual contact with the spinning contents of the spin-drier: contrary to popular belief, there's no 'force field' permeating the space within. **RM**

Will television soon become obsolete?

MIA YARROW, KINGS LYNN

My dictionary defines television as the broadcast of moving images via radio waves. Satellite and terrestrial transmission still use radio waves, but with ubiquitous high speed-internet, these traditional modes could become obsolete.

But away from the semantics, we will still be watching moving images transmitted from one place to another. Television as we know it will finally be a thing of the past when we all view holograms. Three-dimensional images will float before us without the need for goggles. But this is at least 15 to 20 years away. **GM**



Glass is a good insulator, so you're relatively safe sitting at a window during a lightning storm

Can lightning smash glass?

RICHARD O'NEILL, GLASGOW

In 2011, a 10-year-old girl called Erin Moran was struck by lightning while sitting at the window of her bedroom in Merthyr Tydfil. Glass is a good insulator, so it is very unlikely that a window pane would ever be struck directly. But a lightning strike on the roof of a house will travel down through the building through the most conductive route available. The sudden heating of a metal window frame might cause enough expansion to crack the window. The accompanying thunder is caused by the shock wave from the channel of superheated plasma that the lightning bolt creates between the ground and the cloud. This could also shatter a window if it was close enough. In Erin's case, the bolt struck the apex of the attic window, cracked the glass, jumped to her shoulder, passed through her body and out of her foot to the floor. She was left with a snowflake-shaped scar on her arm, but was otherwise unhurt. **LV**



How does the self-cooling can work?

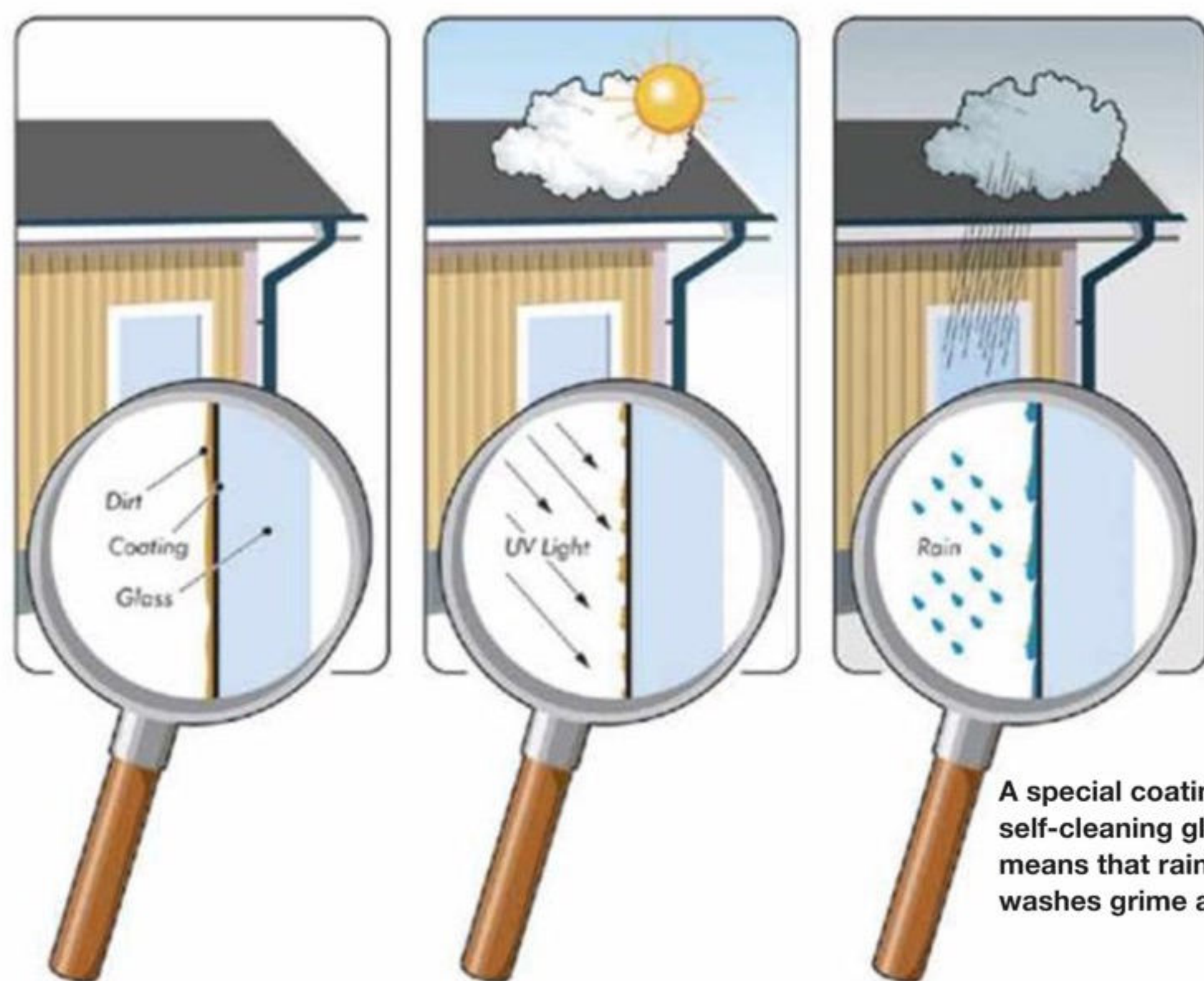
Refrigeration requires something the size of a small cupboard – a fridge is not something you can easily cart around with you. This is a bit of a problem when you want to cool off on the move. Yes, you can buy a cold drink and quaff it on the spot, but the fridge is still dictating when you can have a cold one. The self-cooling can is therefore the Holy Grail of the beverage industry and one man has finally cracked it – Joseph Mitchell's West Coast Chill energy drink is already cooling off Americans with his company's special Chill Can. Push a button at the bottom of the can and it chills the drink by 15°C in just two minutes.

Attempts to solve the problem have been made before. Pepsi was going to introduce a self-chilling can in 1998, but the design used a harmful greenhouse gas and was, err, canned. The Chill Can uses carbon dioxide reclaimed from the atmosphere. The process involved is similar to when your body produces sweat, which evaporates from your skin to cool you down. The can has a heat exchanger that incorporates a pressurised canister of carbon dioxide in contact with the drink. When the button at the base is pressed it opens a valve releasing the CO₂ gas. This causes the gas to evaporate into the atmosphere. As it does so it draws energy from the surrounding liquid, making it ice cold.



FIND OUT MORE

Chill Can news and technology
<http://chillcan.com>



How does self-cleaning glass work?

DAVID LASCELLES, DURHAM

The glass is coated with a microscopically thin layer of titanium dioxide. When ultraviolet light falls on the glass, the layer reacts with organic matter in the dirt, breaking it down into water and carbon dioxide. But there is another feature. The coating also makes the glass hydrophilic, meaning that it takes readily to water. Thus, when the rain arrives, it spreads uniformly across the surface. The sheets of water wash the loosened dirt away evenly rather than streaking in droplets. **GM**

Why is gold rare?

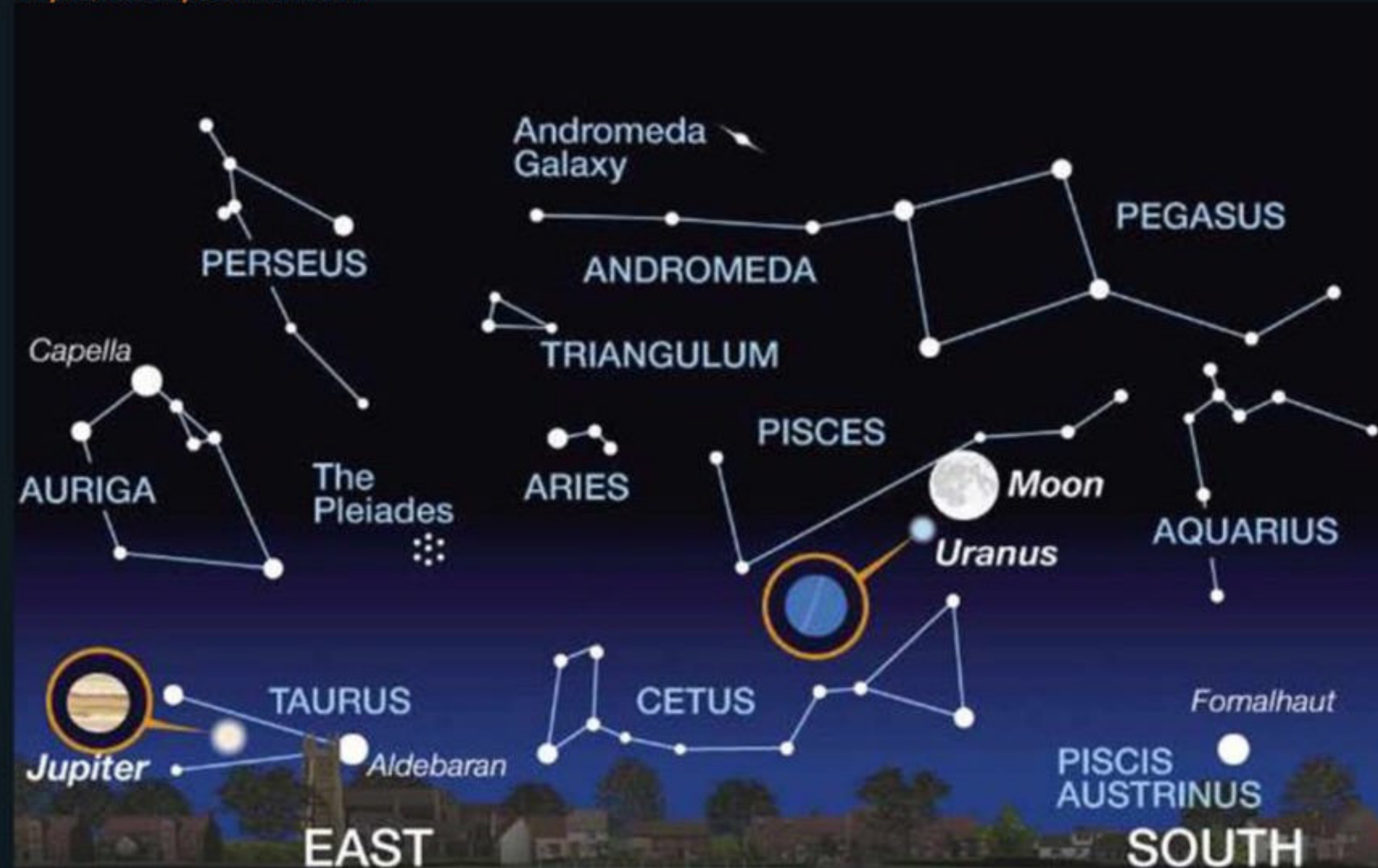
BILL DOBELL, LONDON

Gold owes its status as a precious metal to its rarity: all the gold mined throughout history would fit into a square box with sides of around 20m in length. That's not because of a failure to mine more. Gold is rare throughout the Universe because it's a relatively hefty atom, consisting of 79 protons and 118 neutrons. That makes it hard to produce, even in the incredible heat and pressure of the 'chemical forges' of supernovae, the deaths of giant stars responsible for creating most chemical elements. There's even doubt that supernovae are up to the job. Recent research suggests that even more violent events, such as collisions between neutron stars – the ultra-dense cores of dead stars – may be needed. No wonder the stuff is so expensive. **RM**



Skywatching with astronomy gurus Heather Couper and Nigel Henbest

11pm, 29 September 2012



The almost full Moon lies next to faint Uranus, below the constellation of Pegasus. Also look out for the Andromeda Galaxy, the Pleiades star cluster, and brilliant Jupiter rising around 10pm

What can I see in September?

● 29 September, south, all night

See if you can spot Uranus – the most distant planet visible to the unaided eye. It's at its closest to Earth tonight, and just on the limit of naked eye visibility (you'll need a really clear sky, though!). Cheat by using binoculars or a small telescope – it has a small, greenish disc, and moves slowly from night to night. When William Herschel discovered the world in 1781, he doubled the size of the Solar System.

● 30 September, south, all night

At 4.19am, it's full Moon – but it's also a Harvest Moon. At this time of year, our satellite's tilted path runs almost parallel to the horizon, hardly moving downwards at all. As a result, the Moon rises about the same time each night – making its constant presence ideal for farmers working late to bring in the harvest.

Watch *The Sky At Night* on BBC One. Check radiotimes.com for details

BBC
one



It doesn't take as long to make a brew on Everest

At what temperature does water boil at the top of Everest?

R WEST, CAMBRIDGESHIRE

The boiling point of any liquid depends on the pressure being exerted on it. Roughly speaking, if the pressure isn't very great, then the molecules making up the liquid don't need as much thermal energy to escape. In the case of Mount Everest, the pressure at the summit is barely a quarter the value at sea level, resulting in a boiling point 37°C lower, at just 63°C. **RM**



Why do hens lay unfertilised eggs?

MICHELLE WATSON, ANDOVER

Probably because natural selection had little chance to weed this behaviour out. It may seem odd that hens waste so much protein, fat, calcium and other valuable resources to make an egg that does them and their genes no good. However, our domesticated chickens were bred from jungle fowl and it would be very unlikely that fertile wild hens would ever have escaped the attentions of a cock. **SB**

How do sachets and tins preserve food?

RACHEL BROOKS, KENT

Food is sterilised to kill bacteria before it goes into the tin. For most food this involves pressure cooking it at 116-130°C. Once it is sterilised, the seal on the tin or sachet prevents new bacteria or spores from getting in. Because the container is full, it also eliminates any air, which prevents deterioration from oxidation. **LV**



How does fly spray kill insects but leave people unharmed?

ANTHONY SPARROW, CHERTSEY

Principally because we are much bigger. Most commercial fly sprays use pyrethrins as their active ingredient. These are chemicals derived from chrysanthemum flowers (or synthetic versions of these chemicals) that lock nerves into an 'always on' state. The insect dies because its muscles are all contracting at once so it can't move and quickly suffocates.

Pyrethrins affect human nerves as well, but the chrysanthemum plant evolved pyrethrins to discourage insect predation and it uses chemicals tuned to work best on cold-blooded metabolisms. Our higher body temperature means that the nerve toxin isn't nearly so efficient on us. Add to this the fact that we are five to six million times heavier than a house fly and we'd need huge doses to do any serious harm. The effects of long-term, chronic exposure are still uncertain, however. Some studies have suggested an elevated cancer risk, but pyrethrins are generally regarded as safer than organophosphates, such as dichlorvos, which was banned in 2002. **LV**

NEXTMONTH

What happened to the Space Shuttle?

How do memory sticks hold so much data?

Could Earth be artificially cooled to reverse global warming?

What would you see if you were travelling at the speed of light?

On sale: 20 September

If you can't wait until then, check out the **Q&A** archive
sciencefocus.com/qanda

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The Guide

Everything for the clued-up consumer

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STEPHEN HAWKING'S GRAND DESIGN

The world's most famous physicist returns for a series on science's ultimate goal



Don't be misled by the title – Stephen Hawking has not just completed an elaborate new home. Instead, in this three-parter, the theoretical physicist tackles something even more complicated than building regulations: the possibility that a single theory could explain the entire workings of our Universe.

For decades, physicists have been dreaming up a Theory of Everything: a set of equations that could explain and link together all known physical phenomena, and describe how our Universe was created. Such a theory would, Hawking once claimed, help us to “know the mind of God”.

In this series, which blends philosophy with hard science, Hawking questions the need for a creator, the meaning of life, and the compatibility of science with religion. His narrative, albeit using an actor's voice-over, guides the uninitiated through the brilliant minds and experiments that have shaped physics since the 17th Century and led to the prime candidate for a Theory of Everything – M-Theory.

That might sound like a lot of hard work, but don't worry, Hawking treats physics-phobes gently and layers on the detail one piece at a time. From gravity and light, to quantum bizarreness and string theory, potentially tricky ideas are unpicked with historical

flashbacks and experimental reconstructions. For example, there's a nice football analogy to explain the famous double-slit experiment demonstrating how light can behave as both particles and wave.

Even the perplexing M-Theory is unravelled with impressive ease. The 'M', Hawking says, could stand for 'master,' 'mystery,' or 'miracle,' and posits that the Universe is made of tiny subatomic strings vibrating in a mind-boggling 10 dimensions. But whatever its true moniker, the theory makes one remarkable prediction – that ours is not the only Universe that exists. There are likely to be billions of universes continually popping in and out of existence.

So while M-Theory doesn't disprove God, it could, Hawking argues, prove him unnecessary. The series has the potential to rile creationists and enlighten those with a curious, rational mind. It's a science show with attitude and the world's most famous physicist reassuringly at the helm. “We physicists like strange things,” says Hawking. And with a Universe made of string, it doesn't get much stranger than this.

Helen Pilcher is a freelance science writer

Stephen Hawking's Grand Design premieres on the Discovery Channel on 13 September at 9pm

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The Review Squad

Daniel Bennett

Reviews editor Dan has been taking a look under the hood of the new YouView system that makes it easy to access all your catch-up TV services – p85.



Andrew Harrison

Reviews editor at *PC Advisor*, Andrew did a little programming with the new Raspberry Pi to see if it will inspire people to take up computer science – p88.



Jamie Carter

An internet connection is just as important as a signal when it comes to a new telly. Editor of *Home Cinema Digest*, Jamie looks at four Smart TVs on p90.



Jane Douglas

Gamespot UK section editor Jane spends time with an old friend this month as Lara Croft returns with a *Tomb Raider* exploring her early years (p96).



Dr David Bainbridge

Reproductive biologist Dr Bainbridge reviews Arathi Prasad's new book *Like A Virgin*, detailing our gradual mastery of fertilisation – see p100.



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ONE BOX TO RULE THEM ALL...

The heir to Freeview's throne brings live and catch-up TV under one roof



We're big fans of catch-up and on-demand TV at Focus – just take a look at our review of Smart TVs on page 90. But collapsing into a heap on the sofa and turning on the box after a day at work, you then have to navigate all those different services. But no longer, since YouView hopes to make streaming TV as easy as watching a live channel.

The service puts all the catch-up TV from the core terrestrial channels – like BBC's iPlayer and Channel 4's 4OD – in one place and presents them in an easy-to-browse seven-day programme guide similar to the one already used by most Freeview boxes.

You simply go back to a previous day's schedule to see what TV you might have missed, or search for a whole series that's already aired. On top of this there'll be on-demand TV and films from Sky on a pay-as-you-go basis (prices range from 99p to £3.49). All this is delivered to your set-top box through a broadband connection – so make sure your internet service provider doesn't have restrictive download limits in place.

Just like Freeview, YouView will be accessible through set-top boxes made by a variety of manufacturers. For now the very first box to carry the service is the Humax

DTR-T1000 (we're hoping it is named after Arnie's Terminator), which also carries a 500GB hard drive to let you record live TV.

As Freeview's natural successor, YouView does a great job of putting a user-friendly face on the world of on-demand TV. If you're still watching the likes of *Wonders Of The Solar System* via iPlayer on your laptop, then this is the perfect way to start watching TV you've missed on the big screen.

Humax YouView DTR-T1000

Price: £299

Info: www.youview.com

Objects of desire

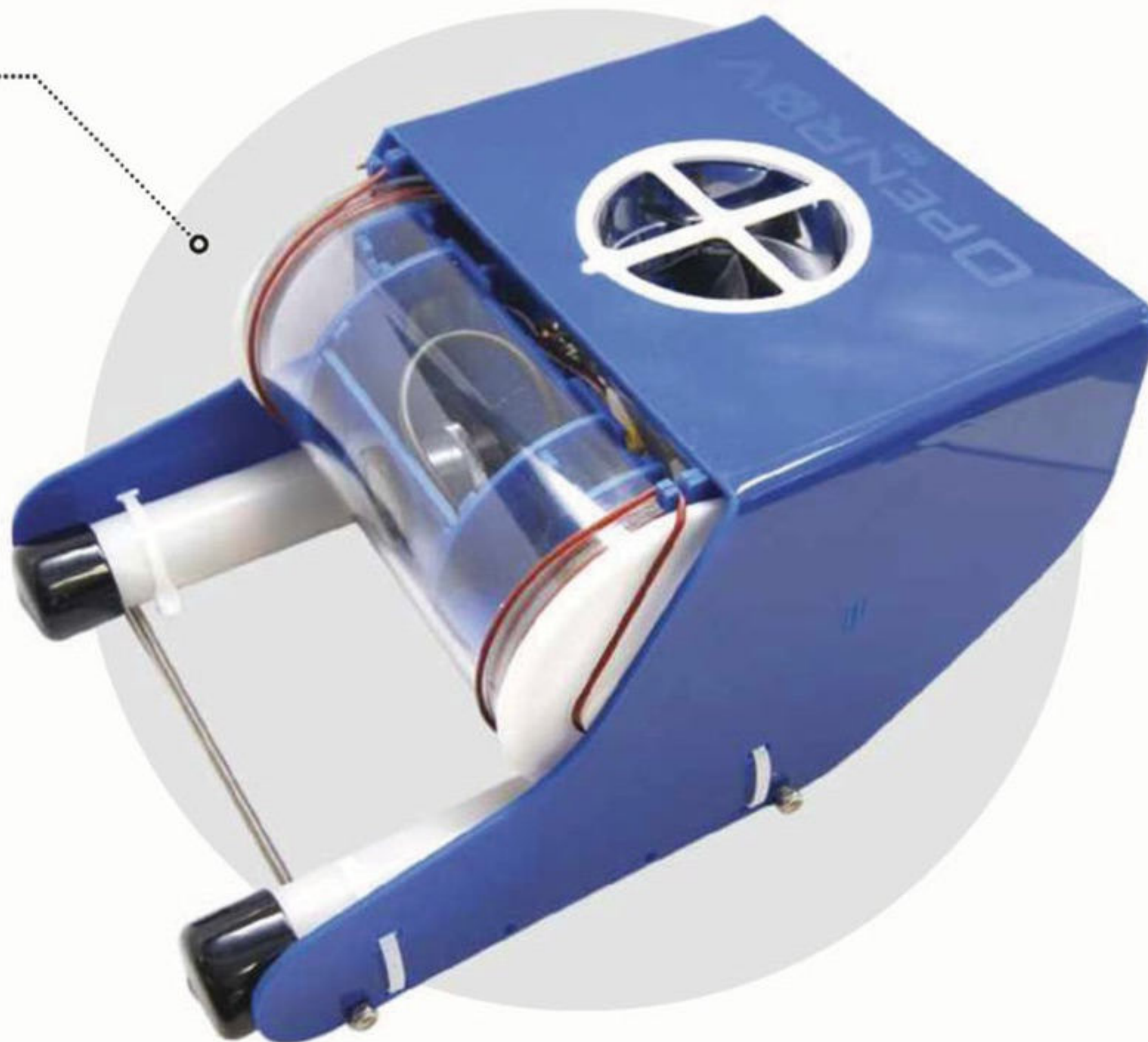
Super sub

If you want to explore the seas but, unlike James Cameron, don't have the spare cash lying around for a submarine, then this open-source project could make you an underwater explorer on the cheap. The makers of this remote-controlled sub hope to encourage citizen scientists to start studying underwater environments, so they've kept costs low by supplying it as a build-it-yourself kit. It's been designed to withstand depths of 100m and will swim around for 90 minutes.

Open ROV

Price: \$775 (£497) plus P&P

Info: openrov.com



Man power

This device lets you charge your gadgets with the power generated from your own body. It sits in a rucksack or bag you're carrying and harnesses the kinetic energy from the vertical movement of walking. This charges an internal battery that can then be used to charge a small gadget, like an iPhone, up to 75 per cent of its capacity. Bear in mind that this early model won't be powerful enough for a laptop or iPad.

nPower personal energy generator

Price: \$169.99 (£108) plus P&P

Info: npowerpeg.com



Radio star

This smart radio can wirelessly stream music from a PC or a smartphone, record audio to a USB stick and add any song you hear to a shopping list you can look at later. It'll also display weather reports, your Facebook and Twitter feeds and photo libraries from Picasa. Or you could just use it to tune into *The Archers* every day.

Pure Sensia 200D Connect

Price: £249.99

Info: www.pure.com



Mini motor

Fancy a car that can go from 0-100mph in under five seconds that costs less than £1,000? The only catch is that at 12cm tall it's just about big enough to seat a hamster. Just like a real racecar, the XO-1 pumps out constant telemetry – RPM, speed, temperature and battery usage – which is transmitted to your remote, and displayed on a smartphone screen. From the telemetry app you can tune the car remotely, altering its braking strength, throttle trim, or steering sensitivity. According to its manufacturers 'The XO-1 is not a toy'. Yeah, right.

Traxxas XO-1

Price: \$1099 (£704) plus P&P

Info: traxxas.com



Barista 'bot

Now that coffee machines seem to have as many buttons, menus and settings as the average nuclear power station, it's a welcome sight to see one that simplifies matters. The fingerprint scanner at the top of this model remembers the unique tastes of up to 10 users so you don't have to fumble around in an early morning haze just to make a cappuccino. Simply press your index finger on the slot at the top and your favourite coffee comes out at the bottom.

Philips Saeco Xelsis HD8946/01

Price: £1,700

Info: www.philips.com

Square up

You might look like a chimp riding a unicycle on this Boxx bike, but that's the price you'll have to pay for convenience. The idea is that this 1m-long, electric bike would sit snugly at the bottom of your car boot – ready for when you reach a busy city centre. You could then park the car at the outskirts of town and ride in, saving yourself money on parking and alleviating pollution in busy cities.

Boxx Corp Bike

Price: \$3,995 (£2,555) plus P&P

Info: boxxcorp.com



Raspberry Pi

Meet the most desirable computer in the world.

Andrew Harrison tests the star of a computing revolution that you can buy for just £30

What is it?

The Raspberry Pi is a complete computer built upon a single circuit board the size of a credit card. Straight out of its plain cardboard box, it won't do much. But pop in an SD memory card with an Operating System (OS) loaded on it, hook it up to a TV or monitor, add a keyboard, plug it into a Micro-USB port for power, and you'll have a working personal computer that costs just £30. Or you can turn your hand to the slightly intimidating command-line interface (CLI) and discover more about computer code.

Why should I care?

Through various input and output ports on the circuit board, it's possible to let the Pi reach out to electric motors, cameras and light, motion and temperature sensors. With a dash of imagination you can create all manner of microprocessor-embedded devices: gadgets like automatic garage-door openers or remote-controlled robots are just the beginning.

The Raspberry Pi Foundation – the charity behind the project – has recognised the watering down of core computer-science learning. The Pi could herald a return to the teaching of computing 1980s-style, when students were inspired by the Acorn, ZX Spectrum – and of course, the BBC Micro – to write their own programs.

What do I need?

The Model B costs just £30. You'll need your own keyboard and monitor (or old TV, thanks to the Pi's analogue video output), an SD card and a USB mains adaptor. For the latter, we used a 5W iPhone charger. To start up your Raspberry Pi, you'll need to load software from an SD card when you first power it up. The best place to start is the beginner's forum at raspberrypi.org. As well as providing a start-up guide, it'll demonstrate the potential of your Pi.

How powerful is it?

The Pi is based on a British-designed chip that was initially made for mobile phones a few years ago. This confers fantastically low power requirements – you

could run a Pi from four AA batteries. The main processor is a clever system that integrates a 700MHz CPU with a graphics processor. In raw speed, it's comparable to a late-1990s 300MHz Pentium II PC. But there's more: this chip was designed for multimedia, and has the graphics horsepower of the first Xbox.

Should I buy one?

If you're interested in computers and gadgets this is a no-brainer. For £30 you get the core component for an ever-expanding list of devices and projects. Don't be intimidated by the unfamiliar software. With a little reading and some support from the helpful Raspberry Pi community, you'll be making new gadgets in no time.

This Micro-USB port gives the Pi its power

3 Things we did with our Raspberry Pi...

Constructed a desktop PC

When we first tried the Pi, the Foundation's website offered two Linux distributions called Debian Wheezy and Arch Linux. These are fully operational but pared-down operating systems that present you with a command-line prompt; typing 'startx' initiates the basic graphical interface. From there you can navigate the system like a Mac or Windows PC and do basic desktop tasks such as word processing and web browsing. But the system does feel slow – you'll need to wait several seconds for tasks that happen instantly on a regular PC.

Difficulty: ●●●●●

Built a mini media player

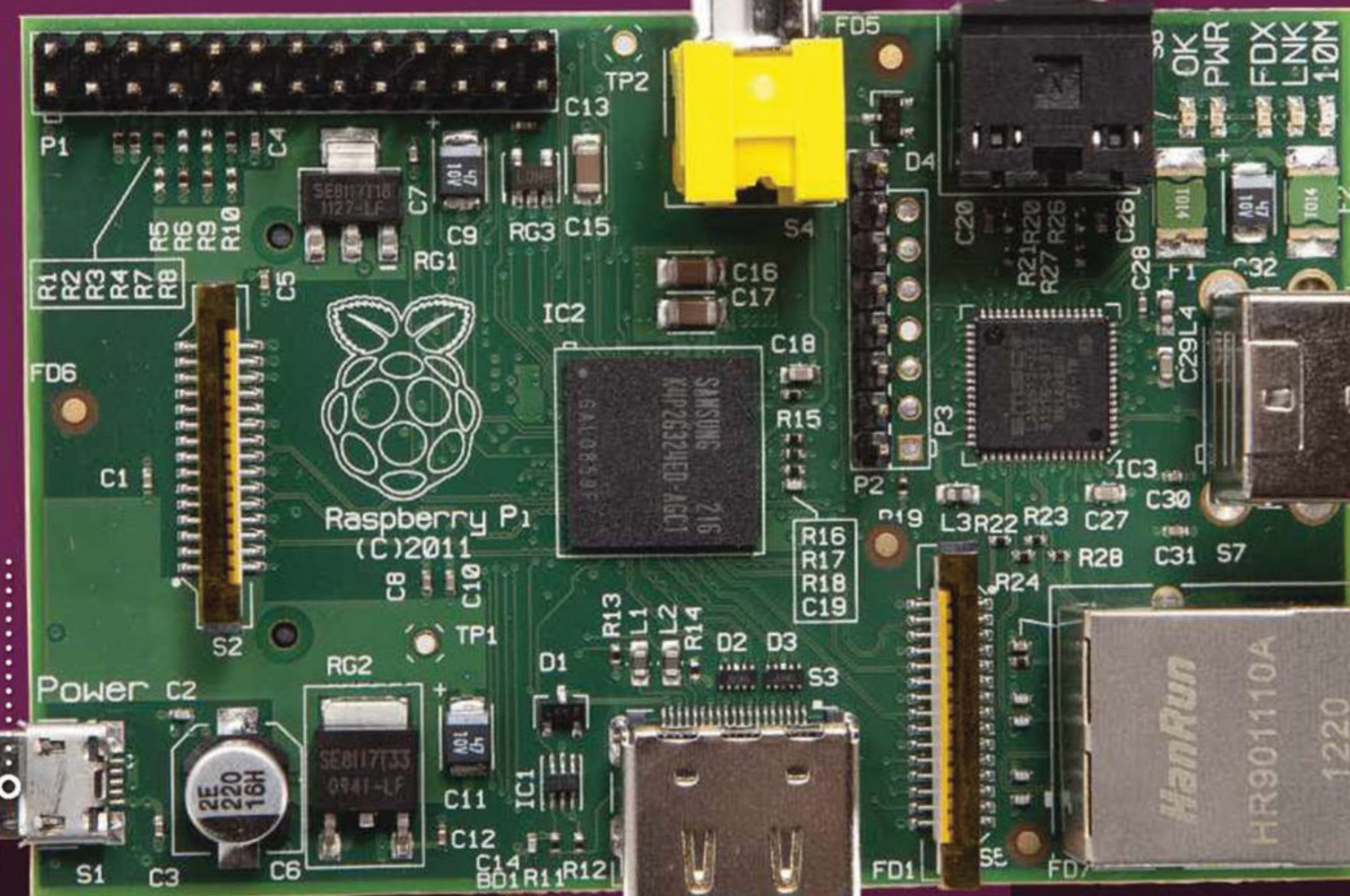
Software called Raspbmc takes advantage of the Pi's graphics potential to make a user-friendly media player for the lounge – think Apple TV. It took a little while to get to grips with, but we were eventually rewarded with a tidy graphical environment that can play video files from attached USB drives or streamed from a hard disk connected to a home network. While standard-definition video played seamlessly, 1080p HD playback was erratic. However, these early software builds are evolving daily.

Difficulty: ●●●●●

Connect the Raspberry Pi to older monitors and TVs, thanks to its analogue TV output

Headphones or speakers can be connected to this audio port

There are two USB ports stacked on top of each other; below is an Ethernet port for a network connection



Learned to code

With a basic OS running, the Pi gives you the environment to learn high-level programming languages, the natural choice being Python, from which the unit takes its name. You can also code in C, C++, Java and even BBC BASIC. But before you dare wrestle with these, complete beginners can play with Scratch – a programming language based around interactive games developed by MIT's Media Lab. Think of it as a kind of safe sandbox, where you learn the basics of programming from a series of interactive prompts.

Difficulty: ●●●●●○

Three more projects to try...

Capture images from the stratosphere

With the help of a USB webcam, amateur balloonist Dave Akerman of Berkshire took photographs of the curvature of the Earth, his unmanned Pload comprising a Pi PC and a GPS receiver. His craft reached an altitude of 40,000m.

Detect intruders and secure your home

With a Pi and video camera kit, you could make your own security camera, complete with motion sensing so that it takes a photo when someone passes by. With its network connection, the Pi could email you to say it had sensed an intruder.

Make your own laptop

Take a retired 10 year-old laptop, remove the guts and replace with a Pi. There are video output pins on the Pi that can hook up to an LCD screen. Power consumption would be so low you could run the laptop for twice as long as the original.

Hi-def video is catered for with this HDMI port

SMART TVs

With dual-core processors, Wi-Fi and apps, the newest TVs have more in common with a home PC than your old set. **Jamie Carter** tests the latest high-tech tellies

What's so smart about them?

These four sets are connected to the internet to provide the best TV the web has to offer. Catch-up services like BBC iPlayer offer the best of terrestrial TV, while the likes of Lovefilm and Netflix provide on-demand streaming of films and TV series, and of course YouTube will give you all the cute kitten videos you can stomach. But that's just the start.

All of these TVs offer smartphone apps that use your home's Wi-Fi network to effectively replace a remote control, while some use Bluetooth-powered touchpads or Nintendo Wii-style wand remotes. If using a physical remote seems so 2010, one set even uses gesture recognition and voice commands for changing channels.

Facebook and Twitter are on the telly now too, and there are dedicated video apps – perhaps the successor to the TV channel – like BBC News or Eurosport that'll bring you specific video feeds for whatever you're interested in. Plus, if you already have a digital library of films, music and photos, then these TVs will stream media from your computer, tablet or smartphone across your network and on to your screen. Oh, and you can watch live broadcasts too.

Do they age like a PC?

Smart TV online platforms are forever adding new apps, new versions of apps, and even completely fresh user interfaces. Each time a platform presents a new app, there's an automatic firmware update – for instance, most of these TVs recently received BBC Sport. It happens at random, so it's best to keep your smart TV connected to the internet (besides, if you don't, most of the apps won't work). In theory, updates will be optimised for your set, keeping your £2,000 investment up-to-date years down the line.

Don't confuse smart TVs with the new YouView, which is available as a separate set-top box or via BT Vision (see our review on p85). Designed as an alternative to a Sky or Virgin Media box, YouView carries catch-up TV from the BBC, ITV, Channel 4, Channel 5 and Sky. In terms of catch-up TV, most smart TVs carry only the BBC iPlayer app.

What else will I need?

A broadband speed of at least 2Mbps is necessary to reliably stream video from iPlayer, YouTube and other on-demand video platforms. Check your bandwidth limit first too, because you're likely to get through around 1GB of data per hour if you're streaming HD films and TV through the internet.

A Wi-Fi router will be useful, but isn't strictly necessary, since these TVs can connect via an Ethernet cable. A 3D Blu-ray player – which now sell for less than £100 – will be useful too, though there still aren't many 3D films to watch. With the exception of the Sony, all of these TVs include at least two pairs of 3D glasses.

What we tested

Interface

It shouldn't take 10 minutes to start watching the last episode of *EastEnders*. Nor should it be complicated to download new apps, watch TV or stream files from your PC.

Visual quality

Featuring the latest in LED backlighting and also offering 3D, these big four flagship smart TVs should offer top quality pictures. But forget about sound – they're all too slim to house decent speakers.

Smart TV apps

Are all the key apps included? Access to the BBC iPlayer is guaranteed, but what other services are provided?

Extra features

Wands, touchpads, smartphone apps and voice control; useful innovations or pointless gimmicks?

Jamie Carter is editor of *Home Cinema Digest*



Panasonic Viera TX-L47WT50B

£2,100

www.panasonic.co.uk



Judged purely on picture quality, this 47-inch Edge LED telly is the best here. Contrast, colour and rich black produce a dazzling, though always accurate picture. The good work carries on with ultra-sharp 3D too, though it's the Viera Connect smart TV platform that we love most. Presenting just seven apps at a time around a live thumbnail of TV, it includes BBC iPlayer, BBC Sport, BBC News, Eurosport, YouTube, Netflix, Acetrax and Lovefilm.

Panasonic's Viera Remote iPhone app is a revelation. We managed to call up some video taken on our iPhone and 'fling' it to the screen with a swipe of a finger, where it played within five seconds. It also worked with websites and photos.



Although Viera Connect is slick and powerful, it's a separate service and not integrated into the TV's core user interface. In some ways that's a positive thing, since the TV's menu system is a tired-looking list that's frustrating to use.

Although it does have a web browser, we had problems loading it and entering search terms, even when we used the iPhone app – it's just too slow – while the touchpad isn't sensitive enough.

Interface: ●●●●○
Visual quality: ●●●●●
Smart TV apps: ●●●●●
Extra features: ●●●●○
Total score: 16/20



Specs: 4x HDMI, 3x USB, Wi-Fi, Freeview HD, Freesat HD, 2x 3D glasses, Touch Pad remote

Samsung UE46ES8000

£1,900

www.samsung.co.uk



You might feel silly spouting dumb phrases like 'Hi TV, volume down' or 'Hi TV, channel up', but this TV's voice control system is surprisingly sophisticated, and because a second microphone is stored inside the Smart Touch remote, there's no need to shout.

Smart Hub has all the key apps, including BBC iPlayer, BBC Sport, Netflix, Lovefilm and Acetrax. On top of software updates, there's a slot on the back of the TV that will be able – via a chip – to update the core picture technologies likely to feature on the brand's 2013 tellies. Future-proof indeed.

Meanwhile, the 3D pictures are bright and precise, and home-made YouTube videos are always clean and watchable.



Ask the TV to launch web-based apps and the software can be a little slow, while using the voice control system properly means learning a list of commands, and keeping background noise down. Gesture control just wasn't sensitive enough, with the TV barely recognising our waves. Meanwhile, Smart Hub is built around Samsung's own rather bland apps like 'family zone' photo sharing and 'fitness zone', which can't be removed.

Interface: ●●●●○
Visual quality: ●●●●●
Smart TV apps: ●●●●○
Extra features: ●●●●○
Total score: 15/20



Specs: 4x HDMI, 3x USB, Wi-Fi, Freeview HD, Freesat HD, 2x 3D glasses, Smart Touch remote, voice and gesture control



Specs: 4x HDMI, 3x USB, Wi-Fi, Freeview HD, 7x 3D glasses, Magic Remote

LG 47LM960V

£1,999

www.lg.com/uk



LG's beautiful borderless 'Nano LED' telly has an equally stunning design on the inside that makes it the easiest TV to use. Governed by an included, motion-controlled Magic Remote that puts a cursor on the screen, the clever interface neatly ties together apps, media streaming, Freeview HD and by far the most user-friendly web browsing.

Its apps include BBC iPlayer, YouTube, Lovefilm, Acetrax, Twitter, Picasa and ITN News, and it's as adept with poor quality web videos as it is with Blu-ray. Seven pairs of specs are included for its unique 'passive' 3D system. For two-player split-screen games, a polarised panel creates two separate images, giving each player a full screen to play on.



When we watched tennis in 3D, horizontal lines were clearly visible. This is because, of the sets we tested it was the only one that uses 'passive 3D'. The technology can't show 3D in hi-def – and it shows.

On the control front, the Magic Remote takes some getting used to as it can easily select the wrong app. Meanwhile the choice of apps on both the TV (no BBC Sport, BBC News or Netflix) and online store wasn't as comprehensive as the others.

Interface:	●●●●●
Visual quality:	●●●●●
Smart TV apps:	●●●●●
Extra features:	●●●●●
Total score:	17/20

Sony Bravia KDL-40HX753

£900

www.sony.co.uk



This 40-inch telly from Sony is a mid-range choice in terms of picture quality, with HD channels, Blu-ray and 3D performing well.

Crucially, it has the same Sony Entertainment Network (SEN) smart service that all 2012 Bravia TVs do: a grid-like screen presents apps (including YouTube, Sky News and Eurosport) alongside special areas for two services called Music Unlimited and Video Unlimited. Both offer material owned and made by Sony (new films cost about £5 to rent in HD), but that does mean more top-line movies than you'll find on either Netflix or Lovefilm, both of which are offered too. Widgets including Twitter and Facebook can be used while you watch TV.



With all of the other LED TVs here having pencil-thin bezels around the screen, this Sony looks a tad old-fashioned. It's also got a rather confused feel, with the SEN interface offered on top of the familiar media bar that also graces the PlayStation 3. Plus, SEN's reliance on Sony-made content feels too corporate. Picture quality is generally excellent, but up-scaling is poor. And no 3D glasses are included, although the price reflects this.

Interface:	●●●●●
Visual quality:	●●●●●
Smart TV apps:	●●●●●
Extra features:	●●●●●
Total score:	14/20



Specs: 4x HDMI, 2x USB, Wi-Fi, Freeview HD

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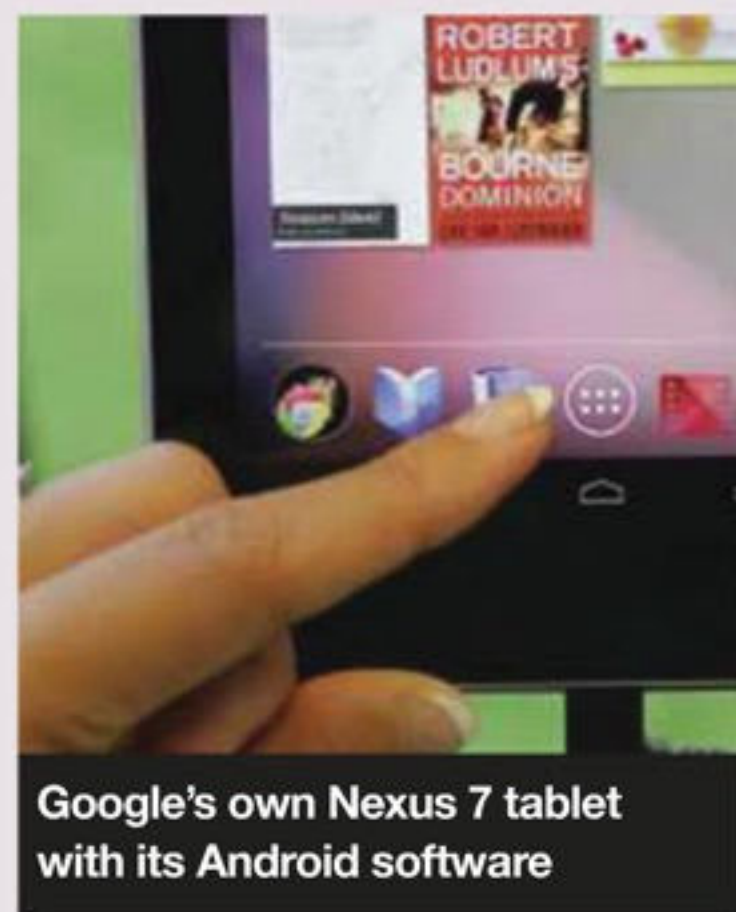


Back in January 2010, I sat in a studio at BBC Radio 5 Live and told the country that Apple wasn't

about to release a tablet – a stupid form factor that was difficult to type on. Steve Jobs, as it turns out, wasn't listening that day, and launched the iPad a few hours later.

As of yet, no one company has really cracked the tablet like Apple has. HP cancelled the TouchPad, Blackberry massively discounted the PlayBook, and even the plethora of Android tablets from different manufacturers haven't made much of a dent in Apple's dominance.

Which may explain why the world's biggest software



companies – Google and Microsoft – have now stamped their name on hardware.

While Apple hardware and software work in tandem, fine-tuned to symbiotic perfection, Android and Windows are mongrels – designed to run on third-party devices. This results in necessary inefficiencies and unavoidable compatibility issues (or crashes, as we lovingly call them).

By putting their names on the boxes of the Nexus 7 and Surface respectively, Google and Microsoft are creating big name brands in a diluted market. And, presumably, by having more of a say in the price and hardware specs, these flagship tablets should better meet the expectations of potential buyers.

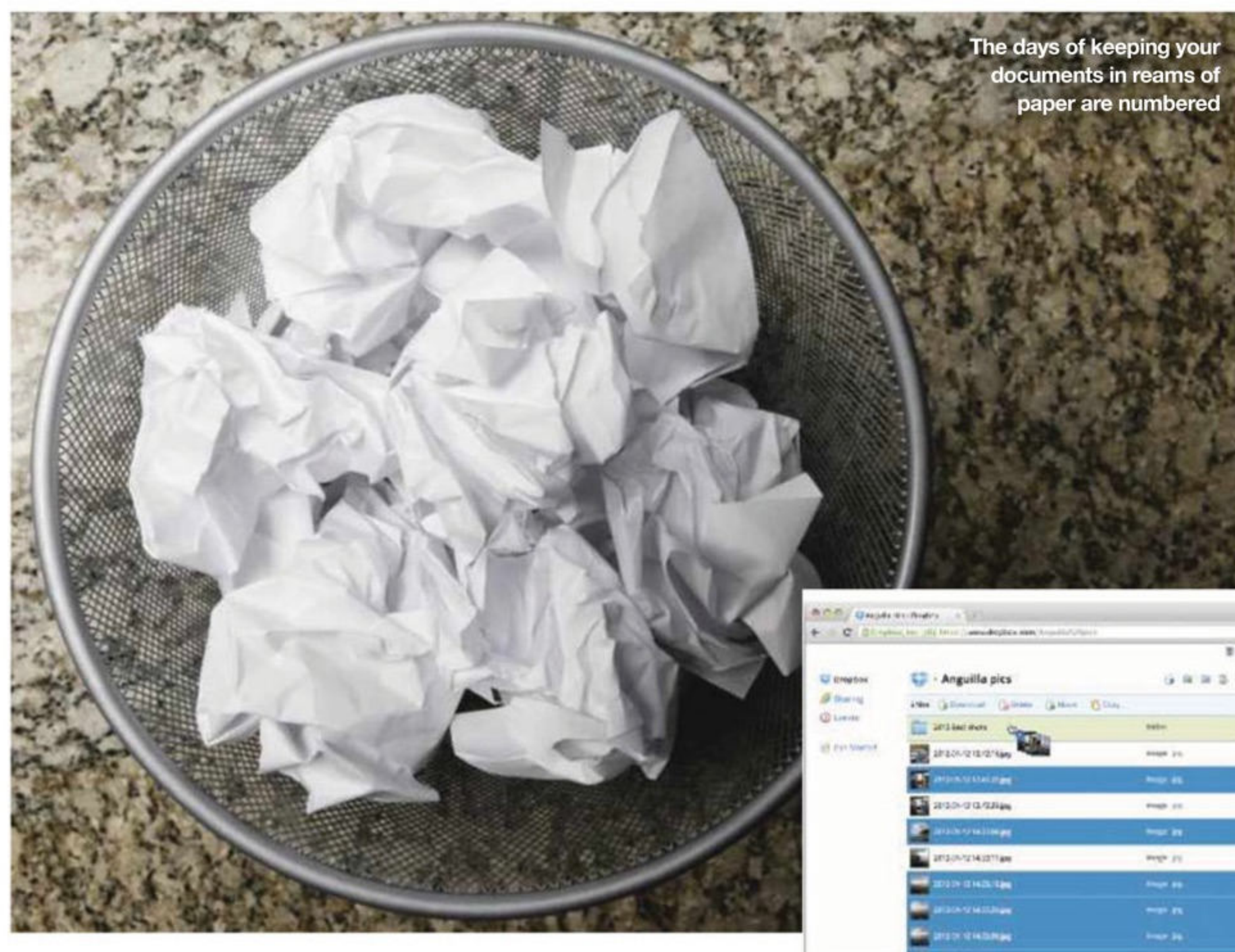
This could mark a sea change in computing, with software giants tailoring their own hardware to perfection. And you'll be the one that benefits.

Spencer Kelly is the presenter of the BBC's technology show *Click*

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The days of keeping your documents in reams of paper are numbered

SCAN IT

While many printers include scanners on top, a dedicated scanner will take a whole ream of pages and scan both sides at once, removing blank pages in the process. Go for one that includes OCR (optical character recognition) software that turns the scanned image into searchable text. Alternatively, use an app on your smartphone. Google Drive for Android or Genius Scan+ for iOS will automatically upload data to the cloud, and have in-built OCR.

SORT AND STORE

A PDF is the preferred file format for scanned documents. Decide on a naming convention and stick to it. For example: date, client name, project name. Once you go paperless, backing up becomes even more important. I use a combination of a NAS (Network Attached Storage), which stores everything on two hard drives accessible via Wi-Fi in case one fails, and cloud storage like Dropbox, which stores everything off-site with top-end security.

CAN I BIN IT?

If you're self-employed, you'll need to keep about seven years' worth of accounts, but you can still throw out receipts, as long as you scan both sides of each and make them available on request. Before you throw out certificates and contracts, check that it's safe to do so with the relevant organisations first. It's best to keep paper copies of land contracts and wills until the law becomes clearer on whether electronic copies are acceptable.

Tech Doc's App Prescription



NHM Evolution

iPad £9.99

This app takes the wonderful palaeoart you'd typically find in a book about evolution and supplements it with interactive 3D models, videos and graphics. Providing a vivid account of the story of evolution over the last 65 million years, it's beautifully organised over one enormous timeline that you drag along the screen.



Photosynth

Windows phone, iPhone Free

This is a DIY version of Google's Street View. Photosynth instructs you to hold your phone's camera up to the world and slowly move around on the spot. As you turn, the app stitches together each photo and when you're done, it gives you a 360° panorama that you can move around.

Playable propaganda



Iranian authorities consider video games another front in a 'cultural war' against their country, waged by

the West through Hollywood movies, satellite TV and the news media. Last year, gung-ho military shooter *Battlefield 3* was banned in the country for scenes set in Iran that were deemed especially provocative.

The ban may or may not have been a blow to the West's agenda in the region, but Iranian game makers are putting the propaganda boot on the other foot. Unveiled at Tehran's very own International Game Expo, *The Stressful Life of Salman Rushdie And Implementation Of His Verdict* is the longwinded title of a video game about the author



Salman Rushdie: virtual target

and the fatwa against him.

It has been designed to remind young people of the 23-year-old death sentence handed Rushdie for *The Satanic Verses*: "It is to introduce our third and fourth generation to the fatwa against Salman Rushdie and its importance," said a spokesman for Iran's Islamic Association of Students, the body behind the game.

Details on its contents are not forthcoming, but it's easy to imagine a low-budget and eventually low-profile affair, not a blockbuster romp – this being an educational title from inexperienced developers.

Games, like any expressive medium, can carry messages we don't agree with. It should come as no surprise that propaganda finds its way into the most modern of our entertainment options. Whether or not you think this is right or wrong, expect more of this kind of game in the future.

Jane Douglas is section editor of GameSpot UK

TOMB RAIDER



In the new *Tomb Raider*, archery lessons have high stakes

PC, PS3, X360
Square Enix
£39.99

The makers of this upcoming *Tomb Raider* reboot liken their take on iconic heroine Lara Croft to Christopher Nolan's *Batman Begins* version of the Caped Crusader. Both game and movie are dark and gritty retellings of their protagonist's origins story – but where everyone is familiar with Batman's canonical beginnings, Lara's are up for grabs. Here, young Lara is shipwrecked on a hostile and mysterious island with a hapless band of survivors. Inexperienced and untested, she must hunt, climb, leap, and kill to stay alive long enough to become the Lara Croft we know and love today.

The game's new signature weapon is the bow and arrow, for skewering wolves and sinister island dwellers alike. The latter in particular are a

nasty bunch, and Lara's escape will entail discovering what they are really up to. Though the basic gameplay feels good, long-time fans will find this is a *Tomb Raider* far removed from the original games, with its desperate shipwreck survival setting and emphasis on human enemies.

Successful though it was for Nolan, 'dark and gritty' as a direction for a reboot is now not so fresh as it once was. And in the course of dicing with that cliché, *Tomb Raider* is curiously fixated on showing Lara muddy, bloody, and suffering. She's a world away from the posh, cocky Croft of years gone by, but there's time yet for the developers to justify their direction and, what's more, to show us some honest-to-goodness ancient tombs.



Tread carefully or you'll end up a suspended corpse

ALSO OUT

FAR CRY 3



PC, PS3, X360
Ubisoft
£39.99

Take a jaunt as unlucky tourist Jason Brody to *Far Cry 3*'s conflict-torn tropical island. There, you'll find the scenery stunning and the locals madder than several boxes of frogs as you explore the game's open world while shooting thugs aplenty. The co-operative mode, which promises free-roaming island adventures with three friends, is particularly tempting.

ROCKSMITH



PS3, PC, X360
Ubisoft
£49.99 (+£17.99 cable)

Where *Guitar Hero* and *Rock Band* offered you fun times on a toy guitar peripheral, *Rocksmith* pledges to really teach you to play. Plug in a real electric guitar via *Rocksmith*'s special adaptor to start jamming to the likes of The Rolling Stones, The Black Keys and Nirvana, in an experience that's part teaching tool, part grown-up rhythm game, and a good deal cheaper than actual guitar lessons.

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Bill Thompson

Can virtual buildings teach us real history?



One of the more interesting sessions at this year's Sheffield Doc/Fest wasn't actually a documentary film, but a presentation about a multimedia project looking at the building of Strasbourg Cathedral.

It incorporated a 3D film about medieval cathedral builders, an interactive web-based documentary, an online game and an augmented reality application, all designed to help viewers understand how the cathedral was made and how it might have looked.

Watching the presentation I felt a real disconnect between the representation of the cathedral and the story told by the actors, and what I understand of the real history of this astonishing cathedral. A disconnect that could not be bridged by high-end computer graphics.

Attempts to represent the past on-screen are not new, of course. But the combination of computer games technology, the latest architectural and historical research and web-based systems now means that we can interact with reconstructions instead of passively observing them. It holds real promise for much deeper engagement.

There are some interesting examples of this online. The Virtual Pompeii project from ProjectVR (<http://publicvr.org>) lets you fly around a model of the theatre district of Pompeii, integrating material from the archaeological dig. And the University of St Andrews has reconstructed the ruins of St Andrews Cathedral and lets visitors wander through the now vanished cloisters (j.mp/AndrewsCathedral).

We can never step back into history, whether our own personal history or that of a society. The past is gone, and we have only its traces to bring it back to memory, but these tools are offering researchers from many different disciplines a way to bring together their findings into a single model that could engage non-experts as well as having real scientific value.

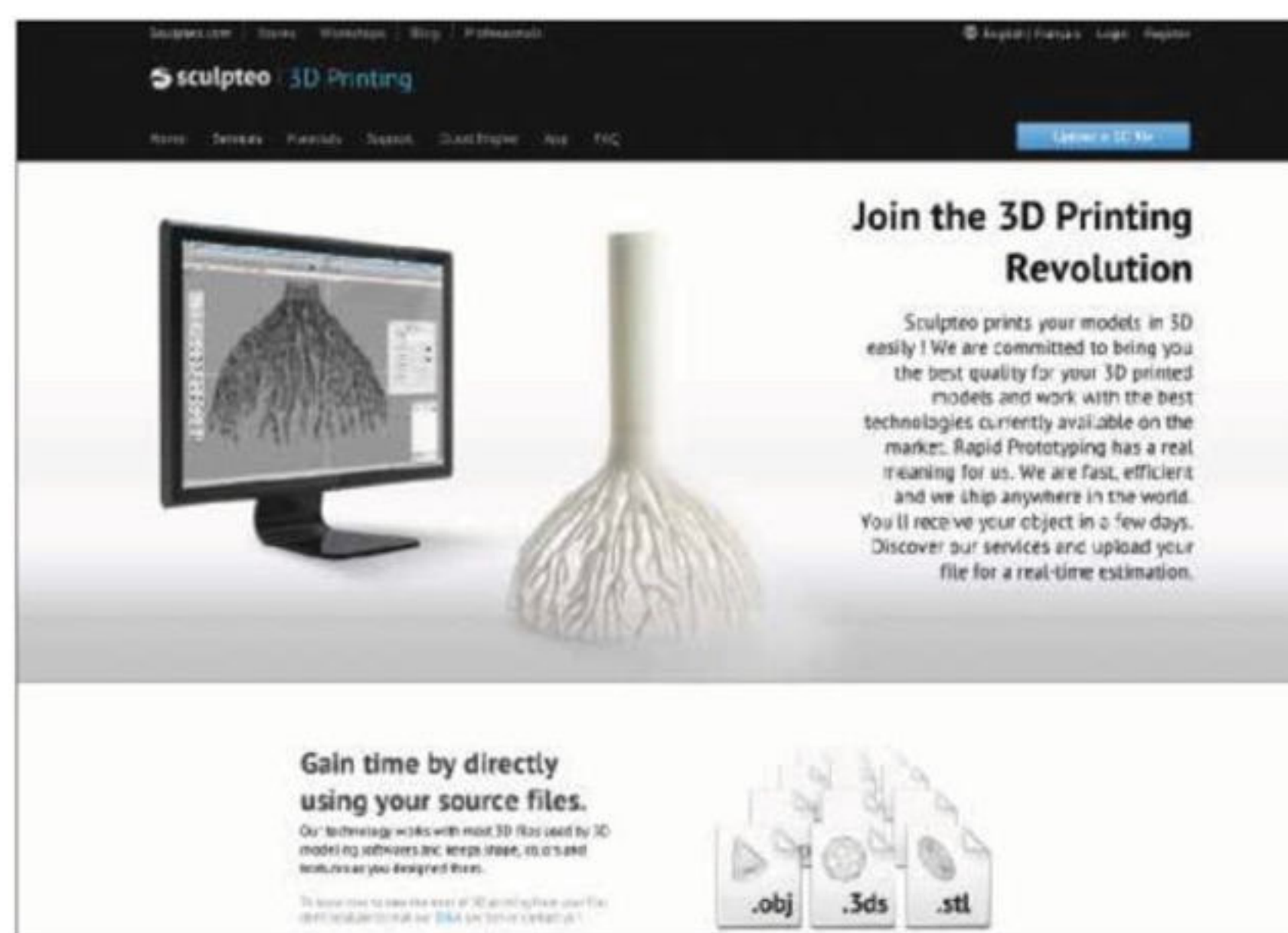
But viewing something on a screen is not the same as being there, and even the best computer-modelled temple won't smell right or have the right texture as you run your hands over the walls. We may have to wait for direct neural interfaces to the smell centres in our brain and touch-feedback gloves before we can really claim to have reconstructed the past.

And even then, I suspect it still won't compete with the emotional experience of actually visiting the ruined St Andrews Cathedral.

Bill Thompson contributes to news.bbc.co.uk and the BBC World Service

Sculpteo

sculpteo.com



If you've got close to £1,000 to spare, or have a hacker mentality and like to build things, then you may already have your own 3D printer creating physical versions of digital objects you've designed or downloaded from the web. But if you find using your old inkjet printer a challenge, or don't have the spare cash, Sculpteo offers an alternative. It's a cloud-based 3D printing service that will print designs – yours or otherwise – for you.

The website provides an excellent overview of what 3D printing is and how it works, and there's a viewer that lets you upload a model file from your computer and check what it would look like. You can even embed the viewer in your own website or blog for sharing with others. There's also a Sculpteo app for your smartphone, and a set of workshops that take you through the process of creating a model. Let the 3D printing revolution begin!

WEB HACKS

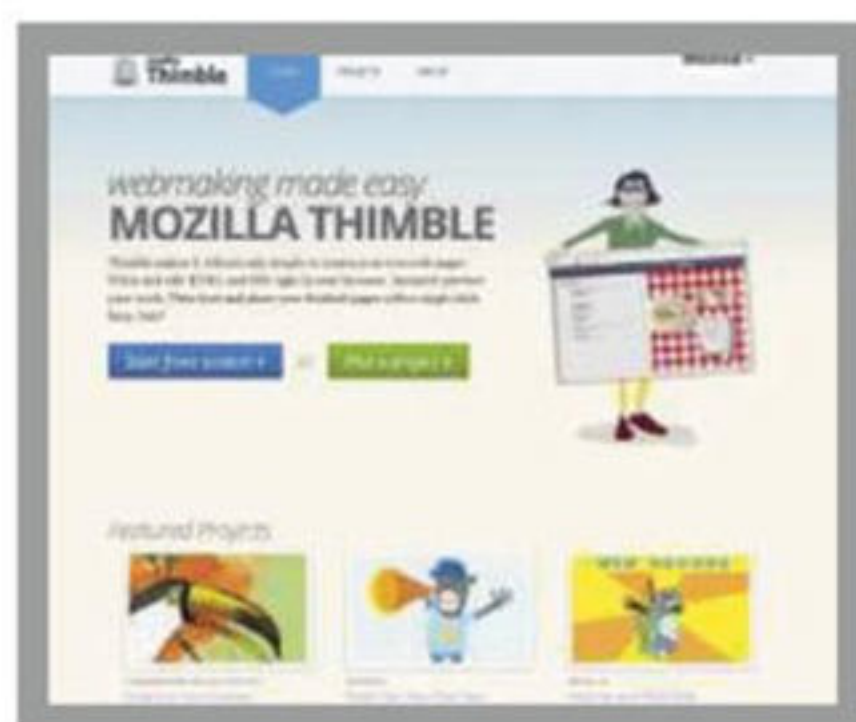
Make website building simple with Thimble

What: Mozilla Thimble makes it easy to create and edit your own web pages, teaching you a bit about how the internet works and enabling you to put up your own stuff online and share it with friends.

Why: Thimble comes from the Mozilla Foundation that makes the popular Firefox browser, and is part of its wider campaign to make us all web-literate. Understanding how the web works is an important skill even if you're never going to build your own website, as it helps you appreciate the limits on what the internet can do, the choices made by developers and the things that can go wrong.

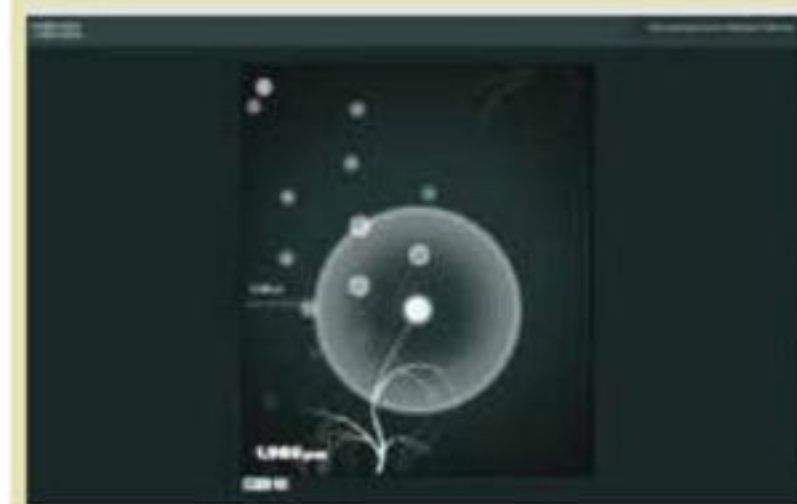
How: You can choose a project to work with and modify, or start from scratch if you're feeling brave. The site will guide you through the steps, show you how your web page is working behind the scenes, and give you your very own URL to share with others. In short, it's a quick and easy way to become internet savvy.

Where: <https://thimble.webmaker.org>



Axon

axon.wellcomeapps.com



Like everyone else, I managed to grow billions of neurones without thinking about it at all, but this lovely little online game from the Wellcome Foundation, part of their larger Brains website, shows just what an achievement that is. You have to grow the axon – the nerve fibre – of a fetal neurone by spotting and clicking on protein targets in the growing brain, competing with other neurones and looking out for special 'boosts'. It's an amusing bit of fun, based on real brain science.

DarwinTunes

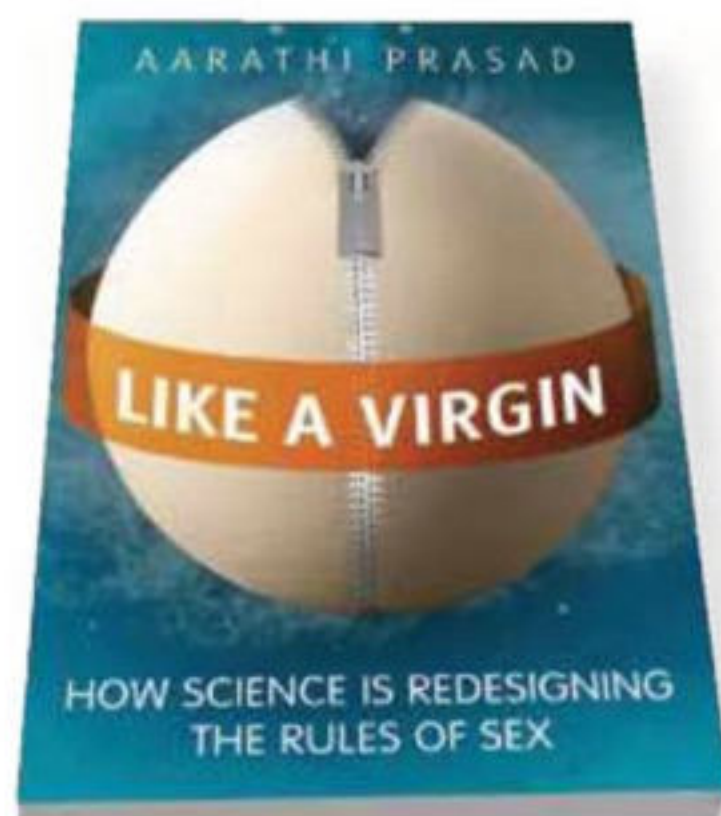
darwintunes.org



DarwinTunes is a lovely little experiment from Imperial College London in how evolutionary modelling can be applied to aesthetics – in this case music. It's a 'Darwinian music engine' with a population of short audio loops that sexually reproduce and mutate as they're rated by listeners, resulting in sounds that become more 'musical' over time. But don't take my word for it – you can listen to the results and help the sounds along by rating them.

Like A Virgin

A fascinating look at the past, present and future of fertility study, says **David Bainbridge**



How Science Is Redesigning The Rules Of Sex
Aarathi Prasad
Oneworld, £12.99
(288pp, pbk)

Making new life is a formidable and perhaps spooky ability, and many of us want to know where the power lies. Who calls the shots: mummy or daddy? And will technology allow either one of them to take absolute control?

In *Like A Virgin*, geneticist Aarathi Prasad takes a long,

historical run-up to look at modern reproductive tinkering. And what a fascinating run-up it is. A lack of microscopes and hormone tests didn't stop ancient philosophers wrangling with the question of who's responsible for making a baby: some venerated women for their generative powers, but others claimed women provided only the base material from which male influence could sculpt new life. Centuries of bizarre reproductive experiments are recounted, as well as media frenzies surrounding human reproductive oddities and technological advances.

A whistle-stop tour through reproductive biology and genetics ensues – cell division, embryonic development, egg and sperm production, placenta formation – as well as some stranger reproductive backwaters, including human embryonic chimaeras, natural virgin birth, and human conception via stab wound. The reader may occasionally wonder if

there's just too much information to take in, but fertility is, quite simply, a complex process that involves more than you might imagine. Regardless, Prasad's humorous and anecdote-laden approach sweeps the reader along.

Later chapters, on the present and future of assisted reproduction, give an intriguing taste of what is to come. This story is, by definition, a work in progress, but the known and the as-yet unknown are clearly described. The author mentions, but avoids becoming ensnared in, moral debates surrounding reproductive meddling. History shows that these debates turn out to be irrelevant: as this book demonstrates, people are only too happy to exploit artificial means of controlling their own baby-making powers.



Dr David Bainbridge is a reproductive biologist and author of *Middle Age: A Natural History*



Dr Aarathi Prasad on Like A Virgin

Why did you write this book?

I started off doing developmental biology and it's always intrigued me. In understanding how egg and sperm develop, we can better understand problems in infertility. A few years after I left the lab, I was a single mother and remember waking up one morning – in my mother's loft, next to my daughter – and thought: 'Hang on, in most animal species, females can have families without males, so why can't women do it?'

What surprised you most?

Stuff you couldn't make up. Until 2006 there was an insurance policy that protected people against having a virgin birth. Also, there are lots of virgin births in nature. There's a species of 'lesbian lizards' that don't have males at all. Even human eggs can be triggered to develop without fertilisation, though mammals can't have virgin births because of a system of 'locks' on DNA.

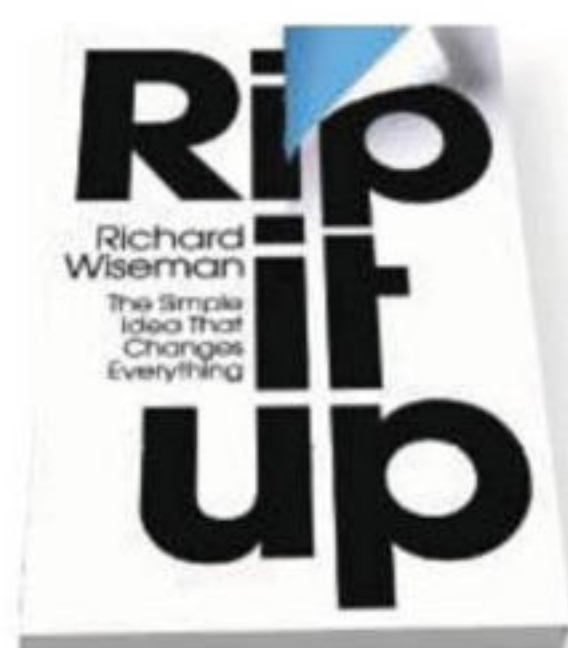
Which part of the book was most challenging?

I found writing about artificial wombs quite hard. Scientists aren't speaking about it because they'd be heavily criticised. Every time a new invention has changed our biologically-dictated abilities, there's been ethical objections – and none so much as with reproduction. When the first IVF baby was born, or when cloning Dolly the sheep, there wasn't discussion beforehand, and there was misinterpretation by some of the media. You could see a similar scenario if a gay couple wanted their own genetic children or if an artificial womb could be healthier than a natural womb in cases where women are taking drugs. We *should* be talking about things that threaten ideas of what it means to be human.

Dr Aarathi Prasad is a writer and broadcaster whose programmes include The Quest For Virgin Birth for BBC Radio 4

Creating life is becoming less of a miracle as scientists unravel its secrets





Rip It Up

The Simple Idea That Changes Everything

Richard Wiseman
Macmillan, £12.99
(pbk, 256pp)

The 'simple idea' of the subtitle is that if we behave as if we're feeling a certain way, our behaviour becomes self-fulfilling. Wiseman's self-help book is laden with examples, such as smiling makes you feel happier, striking dominant poses makes you feel more dominant, and being more active makes you feel less depressed.

The roots of this idea aren't new. Wiseman traces it to a famous 19th Century essay by the American psychologist William James, in which James suggests emotions like fear are a consequence of behaviours such as running away, rather than a cause.

Unfortunately, the book often prioritises sensationalism over nuance. Arranged in sections such as 'mental health' and 'persuasion', findings and theories are cherry-picked to support the over-arching theme. Every other result is described as remarkable, and the implications life-changing. Each chapter ends with an exercise, some of questionable merit, such as ripping out and defacing a photograph of Wiseman's grandfather. But there's little critical analysis of methods or weighing of interpretations.

Given the author's obvious writing talent and the fact that he holds a chair in the Public Understanding of Psychology, this book seems like a missed opportunity.

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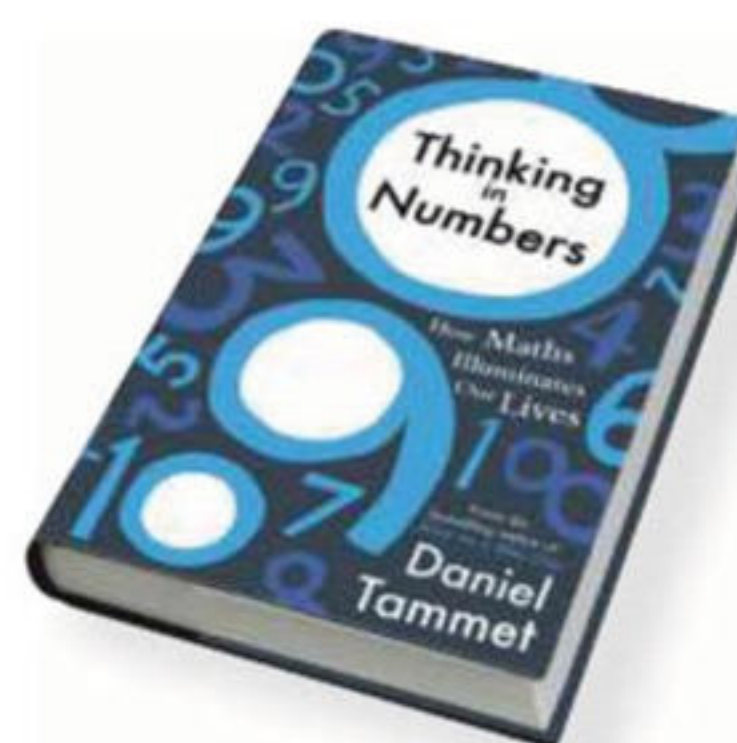
Dr Christian Jarrett is the author of *The Rough Guide to Psychology*

Thinking In Numbers How Maths Illuminates Our Lives

Daniel Tammet
Hodder & Stoughton, £18.99
(hbk, 288pp)

Daniel Tammet is the autistic savant who famously learned Icelandic in a week and memorised pi to 22,514 decimal places. His first book, the bestselling *Born On A Blue Day*, was a charming and insightful memoir of living with Asperger's, and his second, *Embracing The Wide Sky*, a well-received discourse about the potential of the brain.

This third book, *Thinking In Numbers*, is a miscellany of personal anecdotes and how mathematics links to subjects such as history, psychology and literature. He writes that "Mathematical ideas help expand our circle of empathy, liberating us from the tyranny of a single, parochial point of view. Numbers, properly considered, make us better people." I agree entirely.



Tammet's personal experience of Asperger's is what made his first two books such a success, and his fans may find much to like here. But while he has certainly amassed a lot of knowledge, from the rhetoric of Antiphon to the working practices of Vladimir Nabokov, he presents it too often – and perhaps inevitably – it reads like a list of facts and observations. On the other hand, when he talks about his own extreme skills, such as his feat of pi memorisation, the book comes alive.

●●●○○

Alex Bellos is the author of *Alex's Adventures In Numberland*

Wait

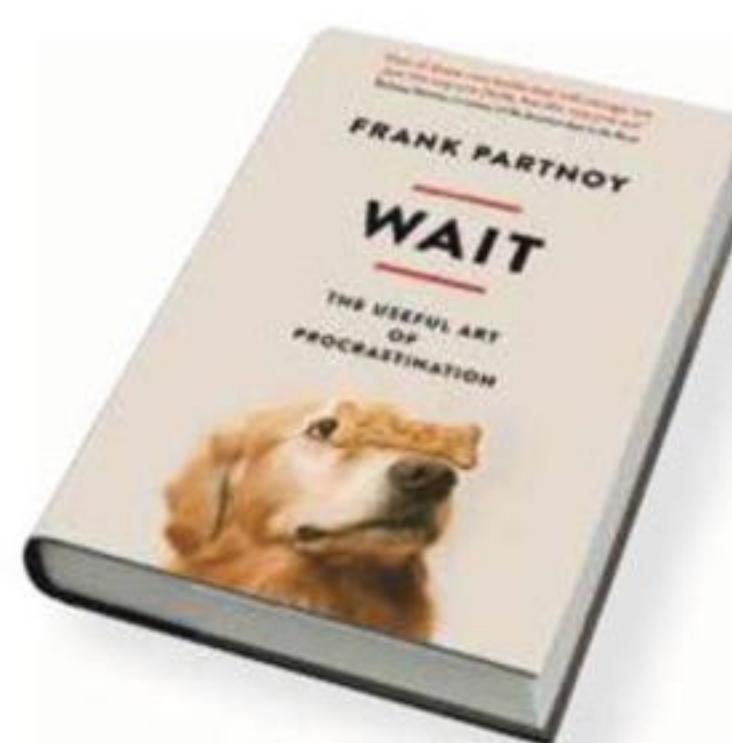
The Art And Science Of Delay
Frank Partnoy

Da Capo, £15.99
(hbk, 304pp)

Do you beat yourself up for messing about and generally not getting on with stuff? Welcome to the club. Studies suggest that almost one in five adults are 'chronic procrastinators' – including the author of this book (and, come to that, your reviewer).

But according to Frank Partnoy, a former Wall Street trader turned academic, we procrastinators weren't always held in such contempt. In Ancient Rome, for example, taking one's sweet time over stuff was regarded as a mark of wisdom. That all changed in the 1970s, when a slew of self-appointed experts commanded us to get on with it, or else. Ever since, faster has been deemed better.

Drawing on a vast range of fascinating insights taken from everything from ancient history to the latest academic research,

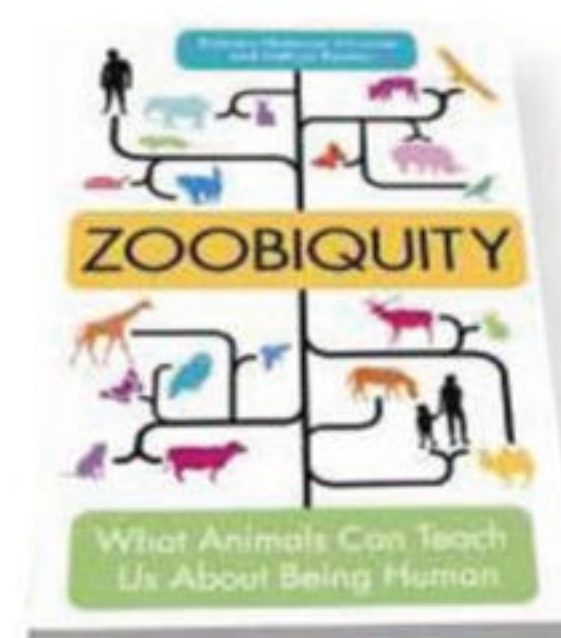


Partnoy argues that we tortoisés can often outperform the hares. He shows that when snap decisions have to be made, only highly experienced experts have a good chance of making the right one – everyone else should recognise their limitations and... wait. And if you think apologies are best offered immediately, think again: some certainly are, but others require a judicious delay.

Partnoy combines solid evidence with entertaining anecdote to make this a book you'll want to race through in no time. Ironical, that.

●●●○○

Robert Matthews is a visiting reader in science at Aston University



Zoobiquity

What Animals Can Teach Us About Being Human

Barbara Natterson-Horowitz
and Kathryn Bowers
Virgin, £12.99
(pbk, 320pp)

The first ever outbreak of West Nile virus in the USA was diagnosed not by doctors treating its human victims, but by a veterinarian at the Bronx Zoo, who was trying to explain a spate of sudden deaths among the birds under her care. This mosquito-borne virus kills mammals and birds alike.

In *Zoobiquity*, cardiologist and psychiatrist Natterson-Horowitz and science journalist Kathryn Bowers lay out the case for better links between the veterinary and medical professions in understanding the origins, causes and treatment of the vast range of illnesses and psychiatric disorders that we humans share with other members of the animal kingdom. Specific topics – each one given its own chapter – include fainting, cancer, sexual disorders, addiction, 'cot death' (Sudden Infant Death Syndrome), obesity, anorexia, hoarding, sexually transmitted diseases, and suicide.

Many of the parallels are striking, especially those – such as self-harming – where biologists' understanding of the motivations of animals outstrips that of (human) psychiatrists. And while some of the comparisons are a little far-fetched (it's not made entirely clear how the sexual habits of barnacles inform us about our own, for example), these comparisons are never less than fascinating.

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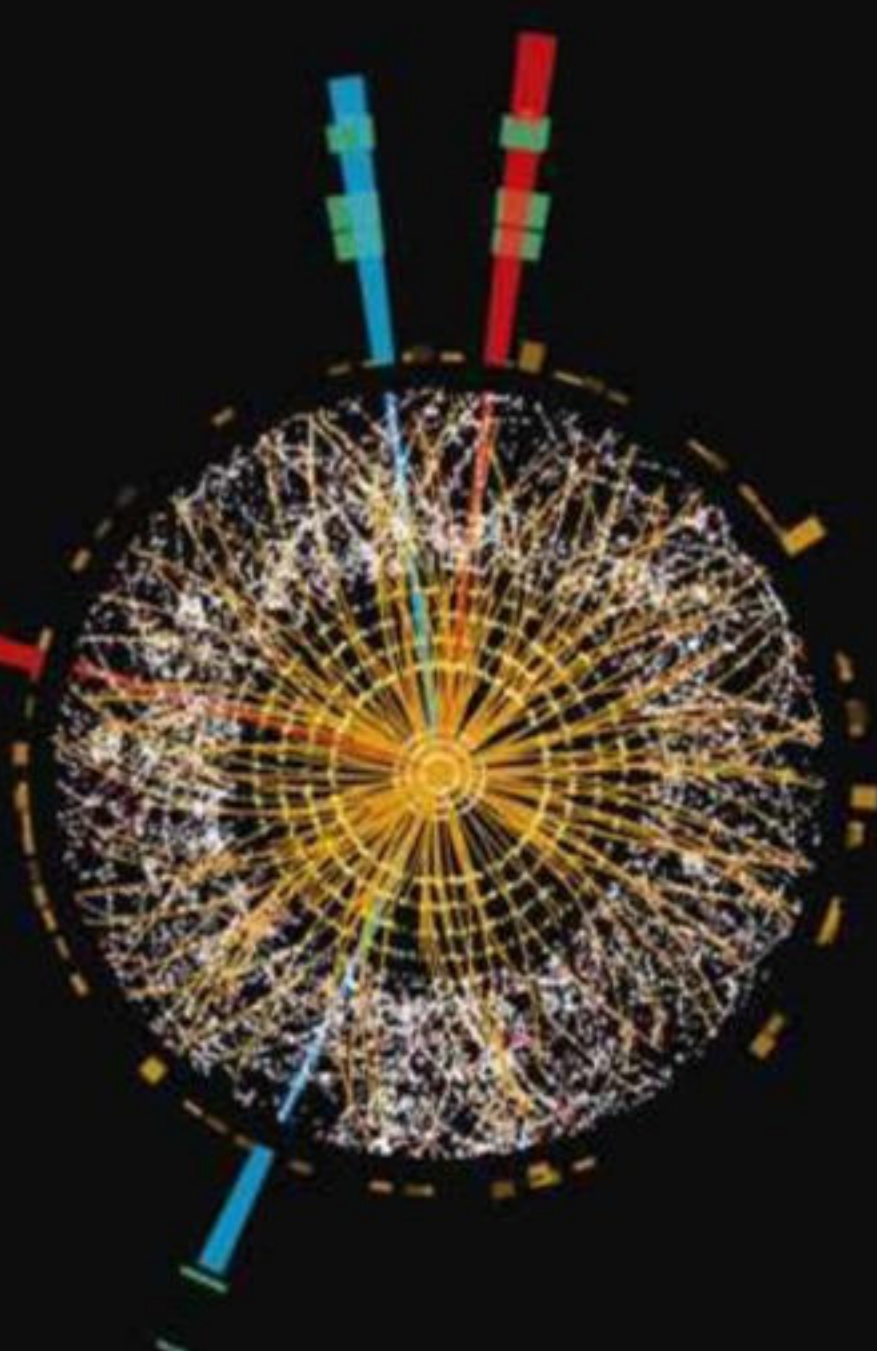
Dr John Bradshaw is the author of *In Defence of Dogs*

SEPT TO-DO LIST

The essential guide to the month ahead

**FROM
23
AUG**

The map of a particle collision at CERN in which the elusive Higgs boson finally turned up



Hunt For The Higgs

With the Higgs boson found – well, *almost* completely certainly found – you might want to learn more about the particle that gives the Universe its mass. Of course you can read *Focus* for that, but if you need to get out of the house, head over to the Science Museum for a new exhibit dedicated to the Higgs. And if that whets your appetite, it'll be followed up with a larger exhibition next year focused on the Large Hadron Collider and all the experiments carried out there.

Science Museum, London, free, www.sciencemuseum.org.uk

30 AUG



Superheroes

Enjoy watching muscular men and lithe-limbed women romping around in spandex? We're talking about the likes of the X-Men, of course. Wellcome Library curator Stephen Lowther explores how true-to-life the heroes and villains gracing our screens and comic books really are, and whether superhuman feats are within the limits of the human body.

Wellcome Collection, London, 7-8pm, free, www.wellcomecollection.org

**1
SEPT**



Globes aren't just the centrepieces of megalomaniacs' evil lairs

Making And Using A Globe

Have you ever wanted to hold the world in your hands? In this workshop, you'll do just that. The earliest known globe was constructed in Turkey in the 2nd century BC and historically speaking, they allowed cartographers to represent the Earth without the distortion that arises from reproducing the planet's surface on paper.

Museum Of The History Of Science, Oxford, 11am, £5 donation for materials used, booking required, www.mhs.ox.ac.uk

**EDITOR'S
CHOICE**

4-9 SEPT

British Science Festival

Every year, this melting pot of science transforms a different city – this time it's the turn of Aberdeen. Highlights include a talk by Brian Cox, who will be sharing his views in 'The Quantum Universe', and an audience with Bill Bryson (pictured) discussing his fascination with science. Exhibitions, workshops and science buskers will also be popping up on the streets of Aberdeen throughout the week.

University Of Aberdeen, prices vary, www.britishscienceassociation.org



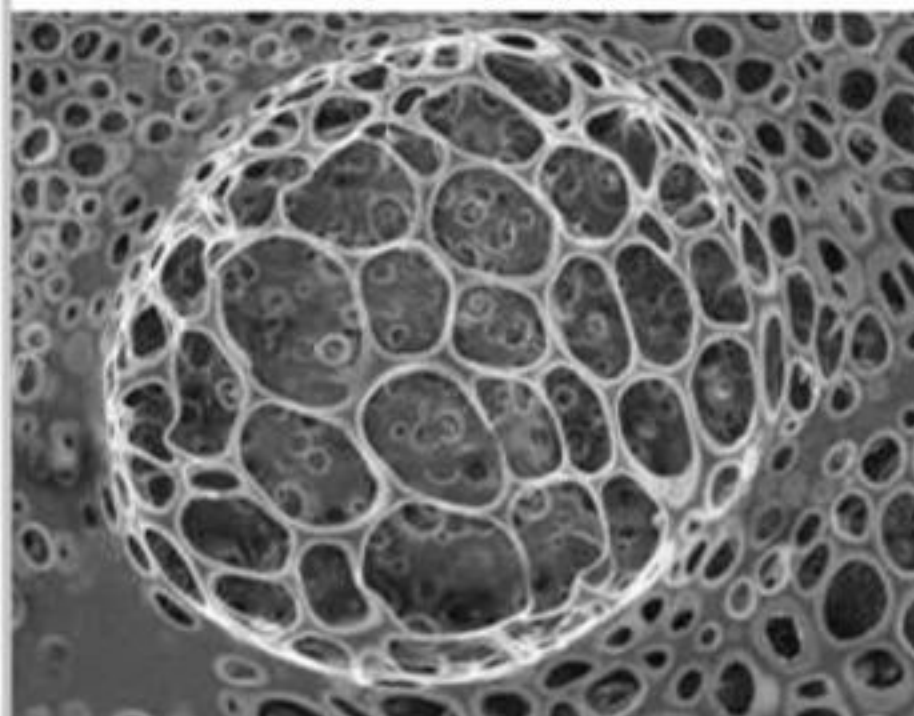
**14
SEPT
-14 OCT**

Magical Materials

From odourless socks to self-cleaning windows and seismic-sensing wallpaper, nanotechnology is creeping its way into household objects. This exhibition reveals the nano-products available right now, and looks ahead to our nano-future. Plus, you get to be an investor for the day and decide which products you'd put your money behind.

Science Gallery, Dublin, free, www.sciencegallery.com

Will this biodegradable polymer turn everything into grey goo?



Find out if Victorian collectors fared better than their specimens

20 SEPT

Birds, Butterflies And Beriberi

Natural History Museum archivist Lorna Cahill reveals inspiring tales of adventure and catastrophe, lifted straight from letters written by stiff-upper-lipped explorers collecting specimens for the museum over the centuries. Natural History Museum, Tring, Hertfordshire, £3.50, booking required, 7-8pm, j.mp/NHMTring

**FROM
21
SEPT**

Astronomy Photographer Of The Year 2012

Once the winners are announced on 20 September, take a look at the stunning images for yourself – there's nothing quite like seeing them first-hand. This year's judges include *Sky at Night Magazine* editor Chris Bramley, the Royal Observatory's Public Astronomer Dr Marek Kukula, and the much-loved, monocled presenter of the BBC's long-running *The Sky at Night*, Sir Patrick Moore. It's on until February 2013.

Royal Observatory Greenwich, London, free, www.rmg.co.uk/astrophoto



Astrophotographer Tommy Eliassen's 2012 entry showing the Northern Lights

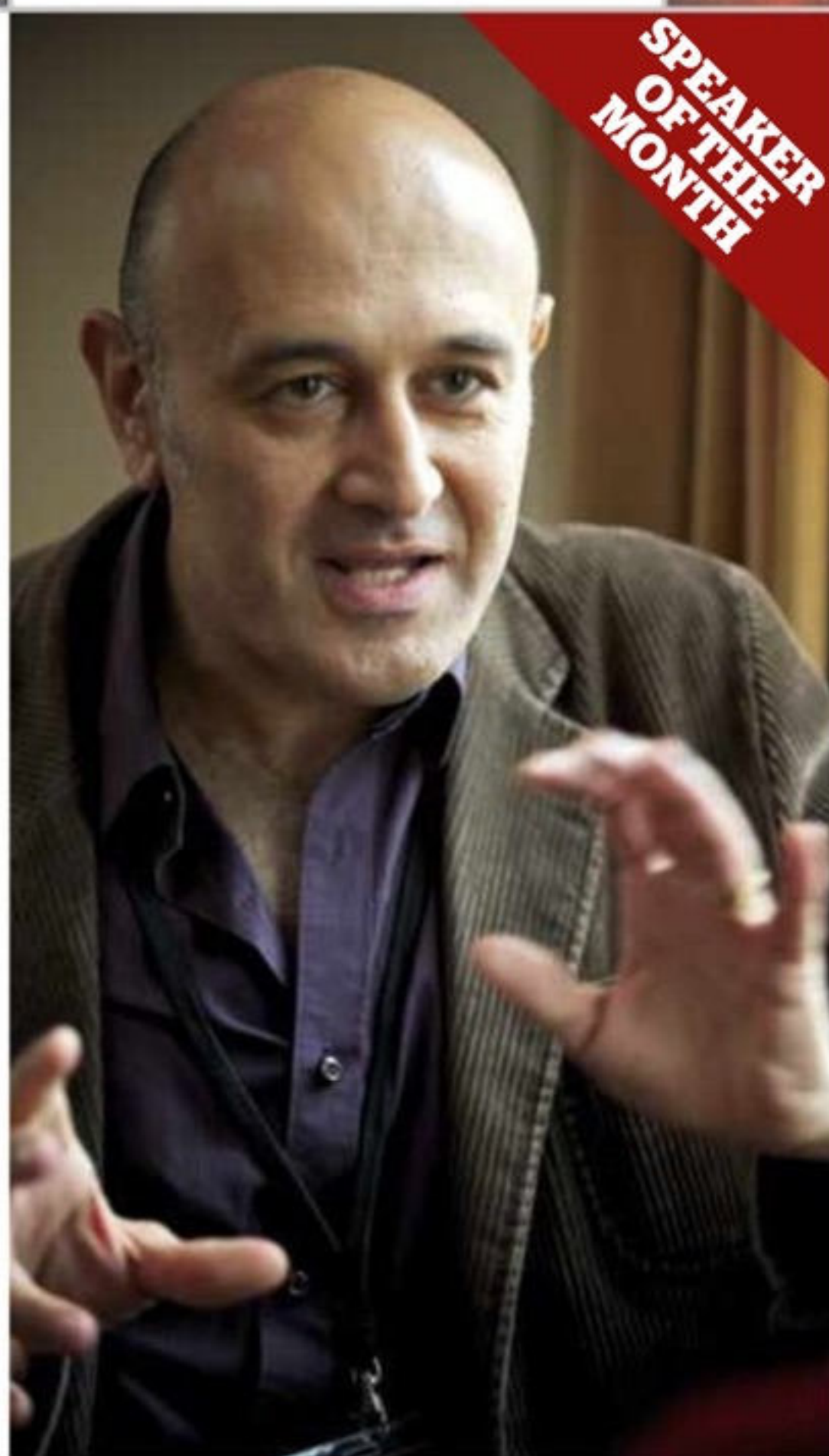
25 SEPT

Prof Jim Al-Khalili

In between presenting his BBC Four series *Shock And Awe: The Story Of Electricity* and his research in nuclear physics at the University of Surrey, Jim's found time to write a new book *Paradox: The Nine Greatest Enigmas In Science*.

Based on his book, this talk explains the quandaries that have puzzled scientists in the past, and those that have left them still scratching their collective heads. In just one session, you could find out the answers to such questions as whether the Universe is infinite, if we really have free will or if it's possible to travel back in time.

Royal Institution, London, 7pm, from £5, www.rigb.org



**SPEAKER
OF THE
MONTH**

**UNTIL
29 SEPT**

Anatomy Of An Athlete

If you've got Olympics-withdrawal and need something to fill the void left by the Games, then catch this exhibition before it packs up and leaves too.

Set in the Hunterian Museum, which collects surgical and anatomical artefacts, a portion of its galleries has been dedicated to the science that propels Olympians and Paralympians alike. There are scale models of athletes' physiques, presentations illustrating how hamstrings are surgically re-stitched and videos capturing the moment muscle injuries occur.

Hunterian Museum, London, free, j.mp/Hunterian



**LAST
CHANCE TO SEE**

TV & RADIO

The month's top science programmes

Miniature Britain



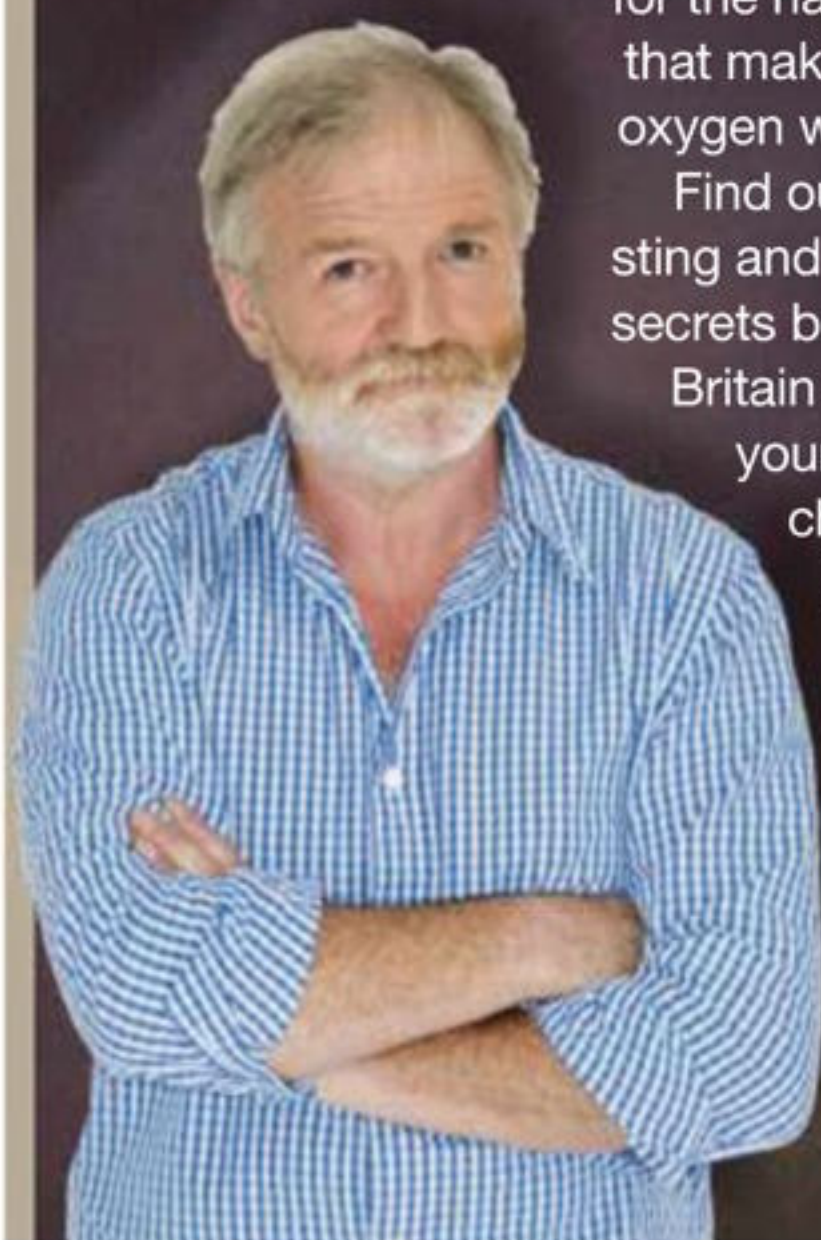
BBC One
September

Presenter George McGavin is a professional insect bather – an entomologist – but after the success of the series *Afterlife* he's branching out. In this programme he uses state-of-the-art microscope cameras to show us Britain as we've never seen it before – up close and in alarming detail.

He'll visit the nation's forests, grasslands, coastlines, rivers and lakes to examine them in extraordinary depth. McGavin takes us down through smaller and smaller scales, from worms that can travel a mile a day and bees pollinating flowers, down to tiny marine creatures too small

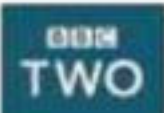
for the naked eye to see that make most of the oxygen we breathe.

Find out how nettles sting and many other secrets behind life in Britain today. And brace yourself for all your children wanting a microscope for Christmas. You have been warned!



These ants are giants compared to some of the creatures featured in the programme. Inset: presenter George McGavin

How Big Is The Universe?/How Small Is The Universe?



BBC Two
September



This mind-bending two-parter is all about the unfathomable scale of the Universe. On the one hand there's the Planck Length: the smallest scale that's theoretically possible – think of it as the smallest size that anything can be ($1.6 \times 10^{-35}m$, in case you were wondering). And on the other there's the size of Universe itself. If you're struggling to imagine the scope of either of these, don't fret, as scientists around the

world face the same problem. To find answers, the *Horizon* team visits the particle physicists trying to understand the very fabric of the cosmos and the astronomers hoping to chart its ever-expanding edges.

Genius Of Nature



BBC One
September



Engineers and scientists will look anywhere for new ideas. And as Richard Hammond shows in this series, they're not above pinching ideas from the natural world. So he goes in search of giraffes in Botswana and hagfish in the

Pacific, and uses experiments to demonstrate what makes their natural adaptations so effective. Then he finds out how these principles are being applied to technological innovations.



Richard Hammond:
in search of
slime eels and
other marvels
of nature

The Life Scientific
Radio 4, Tuesdays, 9am
Prof Jim Al Khalili's guests in September include doctor, mountaineer and researcher Hugh Montgomerie, and chemist Andrea Sella, whose explosive performances thrill audiences and terrify risk assessment form-fillers. As ever, the chat will range across work and play, science and personal lives, in Al-Khalili's relaxed style – though on 4 September he plays host to evolutionary biologist and irascible atheist Richard Dawkins, so the atmosphere could get more volatile.

Your Starter For Ten: 50 Years Of University Challenge
Radio 4, 25 August
If you remember the first broadcast of *University Challenge* then you remember the '60s – and so, according to some, weren't there! But perhaps while your fellow students were trying to smoke banana peel, you had the satisfaction of answering some obscure question on the Emperor Constantine instead. Now you can revisit 50 years of the addictive quiz show. Your starter question, then: which team defeated Scumbag College in their only *University Challenge* appearance?



Saving Species
Radio 4, starts 4 September, 11am
Radio 4 welcomes a new season of Brett Westwood's live show about conservation. Each week's content depends on unpredictable factors like the weather and the migration habits of Californian condors, but expect to hear about bats, forests, the sexing of turtles and satellite-tagged cuckoos. You can also find out how the wet summer affected UK wildlife, discover the impact of wind turbines on migrating birds and catch up with a glow worm survey in Devon.

World's Top 5



Quest, starts 13 September, 9pm

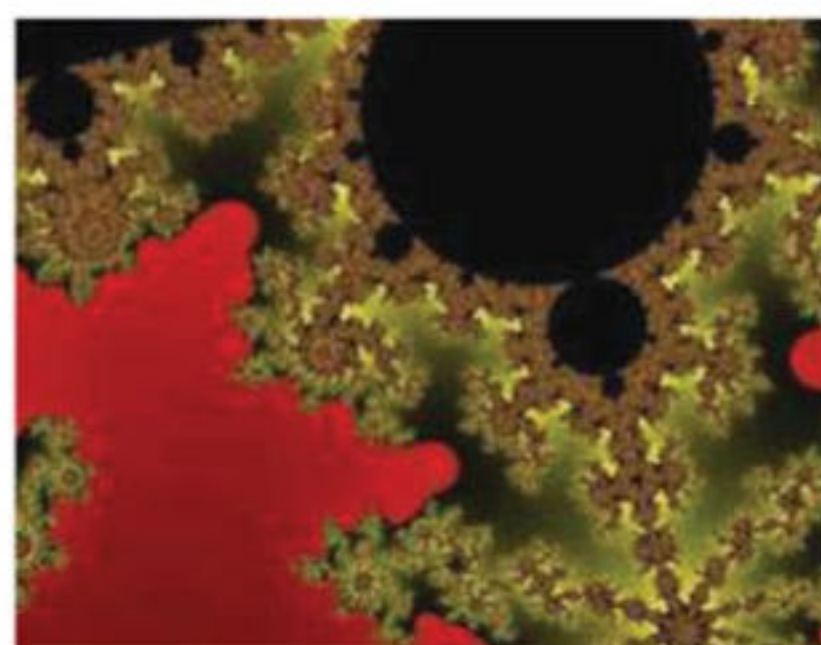


Like a glorious engineering Top Trumps, this series takes the most impressive machines in a series of categories, including planes, trains and automobiles, and tests them against each other, raising serious questions like: how do you make a fighter plane that nimble without it falling out of the sky? Can you have a train without wheels? And will we ever grow out of saying "Wow! Look at the size of that thing!"?

Hunting The Hidden Dimension



Discovery Science
12 September, 9pm



Fractals – repeated patterns that stay intricately detailed no matter how closely you zoom in – are not just a way to make psychedelic images. They're also a branch of mathematics pioneered by Benoit B Mandelbrot. In this series, we join the late Mandelbrot himself on his quest to decipher the secrets of this endless game. From broccoli to cloud formations, fractal dimensions appear to defy the normal rules of mathematics.

Great British Railway Journeys



Yesterday, starts 3 September, 9pm

In the 19th century, as railways transformed the British landscape, cartographer George Bradshaw recorded their impact. In this series Charlie Bunce and Michael Portillo use Bradshaw's records to tell the story of the UK's trains and the people who run them. Once the only reliable way to travel faster, railways are now a record of social change and industrial revolution.



Bionic Builders



Discovery Science
19 September, 9pm

Casey Pieretti is a Hollywood stuntman and an amputee. In this programme he works with engineer Bill Spracher on prosthetics that enable the wearer to be not normal, but better than normal. For instance, a one-handed martial arts instructor gets a new punching arm that's more *Bionic Man* than *Karate Kid*, and a former Navy diver wants to be a human torpedo. Minus the exploding head, we hope.



Yellowstone



Eden, starts 11 September, 8pm



The USA's Yellowstone National Park is a geological wonderland. With more geysers than the rest of the planet put together, it's the most extensive thermal area on Earth. No wonder: lying dormant beneath it is the world's biggest volcano. But as this three-parter reveals, it's also home to wildlife including grey wolves, grizzlies and the last great herds of American Bison. Not to mention Yogi Bear.

Animal House



Eden
21 September, 6pm



Ants don't have to get planning permission and star-nosed moles never worry about the local schools, but every animal needs a home. And for interior design, we couldn't beat the house-proud bower bird. David Attenborough narrates the stories of birds, beasts and bugs whose houses include larders, nurseries and high-rise living. Hornets with electric central heating? Are they kidding? Don't they know that gas is cheaper?

BRAINTRAINING

Pit your wits against these brainteasers by **David J Bodycombe**, question-setter for BBC Four's *Only Connect*

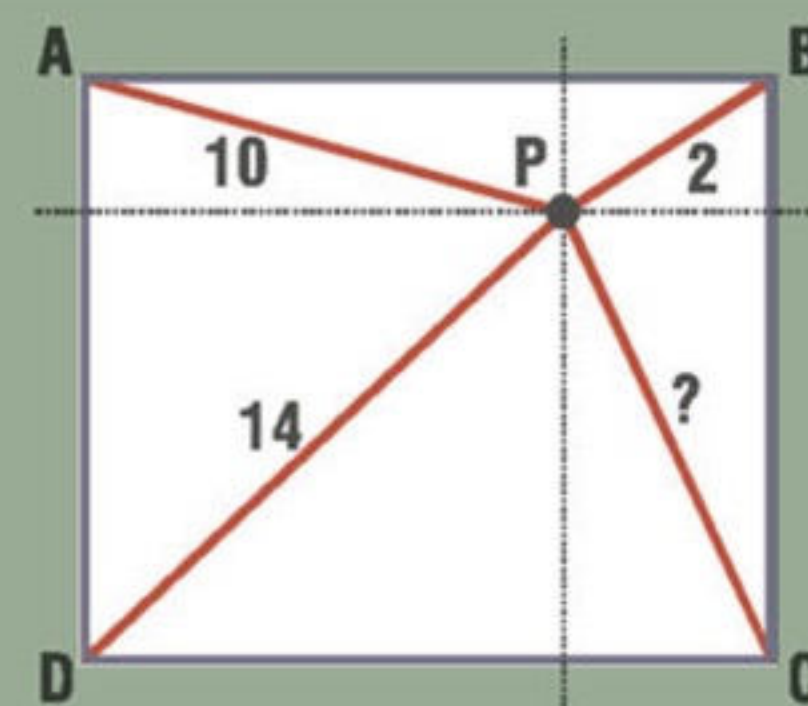


Prize Puzzle

Find the length of the diagonal PC

The first five correct entries drawn will win a copy of BBC *Planet Dinosaur 3D*. Post your entry, marked 'Prize Puzzle 246', to Focus Magazine, PO Box 501, Leicester, LE94 0AA, by 5pm on 20 September 2012. We regret that we cannot accept email entries for this competition. See bottom of p82 for terms and conditions.

Congratulations to Peter Haworth (Bristol), Brian Sharp (Somerset), R Tindall (Cambridge), Anne Miller (West Yorkshire) and John Mason (Cambridge), who all answered July's Prize Puzzle correctly to each win a copy of *How To Teach Relativity To Your Dog* by Chad Orzel.



See sciencefocus.com/winners for previous winners and solutions

QUESTION 1

What's the link between a gallon of water and Charles Darwin?

QUESTION 2

Choose one letter from each line to obtain another colour:

YELLOW

PURPLE

BLACK

GREEN

GREY

RED

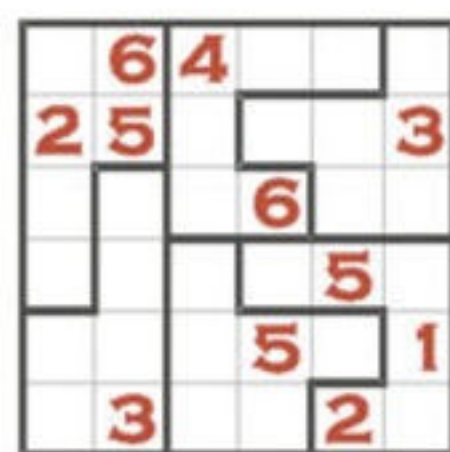
QUESTION 3

According to Lagrange, every whole number can be expressed as the sum of just [X] square numbers.

- What number is [X]?
- What is the first whole number to require [X] square numbers?

QUESTION 4

Fill in the boxes so that the digits 1 to 6 appear in each row, column and marked shape:

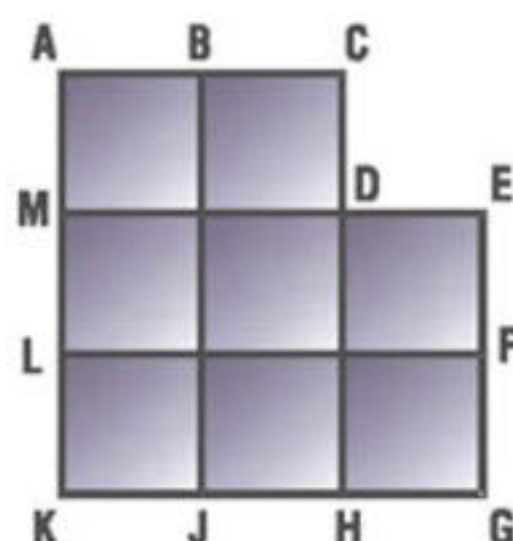


QUESTION 5

In the 1966 Le Mans 24 Hours race, the car that crossed the finishing line a close second was judged to be the winner. Why was this the case given that there was no disqualification or appeal?

QUESTION 6

Use two straight cuts between any of the points marked so that the pieces can be arranged into a square shape:

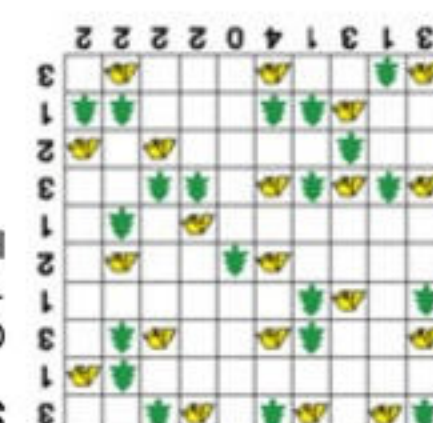
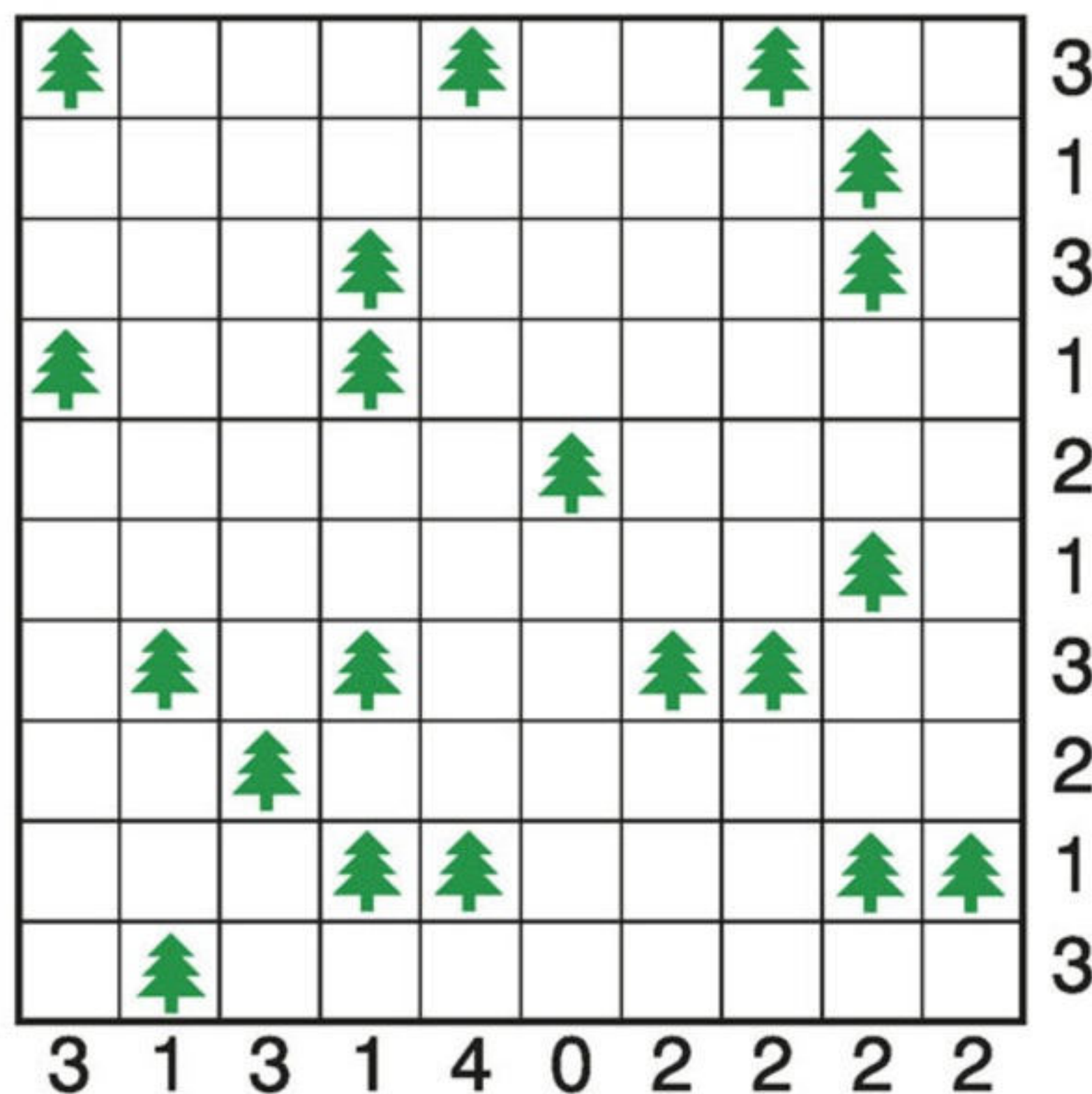


QUESTION 7

Computer game designer Shigeru Miyamoto noted that sumo wrestlers used two scales to weigh themselves (they add together both readings). This gave him the idea to create which gaming device?

QUESTION 8

Place tents in the empty squares so that the number of tents in each row and column matches the numbers shown. Every tent must be immediately next to a tree (horizontally or vertically). One tent per square only. Tents are never adjacent to each other – not even diagonally.



Solutions

Q1 Charles Darwin appears on the back of a £10 note. An imperial gallon of water weighs 10 pounds. Q2 ORANGE. Q3 (a) Four; (b) 7 ($2^2 + 1^2 + 1^2 + 1^2$). Q4 Row by row: 164235, 251463, 345612, 412356, 623541, 536124. Q5 The 2nd car began further back in the starting grid, so it had actually completed a further distance in the given time limit than the apparent 'winner'. Q6 Cut from K to D and M to H. Q7 The Wii balance board. Q8 See illustration.

Quick Quiz

Test your knowledge on the circulatory system

QUESTION 1

1) Approximately how many times will the average human heart beat during a lifetime?

- a) 2.5 million
- b) 2.5 billion
- c) 2.5 trillion

QUESTION 2

2) Blood is one type of fluid that moves through the circulatory system. What's the other?

- a) Bile
- b) Urine
- c) Lymph

QUESTION 3

3) Which blood vessels carry blood towards the heart?

- a) Veins
- b) Capillaries
- c) Arteries

QUESTION 4

4) The human heart is divided into how many main chambers?

- a) 3
- b) 4
- c) 5

QUESTION 5

5) What's the name of the largest artery in the human body?

- a) Pulmonary artery
- b) Umbilical artery
- c) Aorta

QUESTION 6

6) Ibn al-Nafis, the Arab physician who first described the pulmonary circulation, lived during which century?

- a) 13th Century
- b) 15th Century
- c) 17th Century

QUESTION 7

7) Roughly how many litres of blood are there in the average adult human body?

- a) 5
- b) 15
- c) 25

YOU ARE:

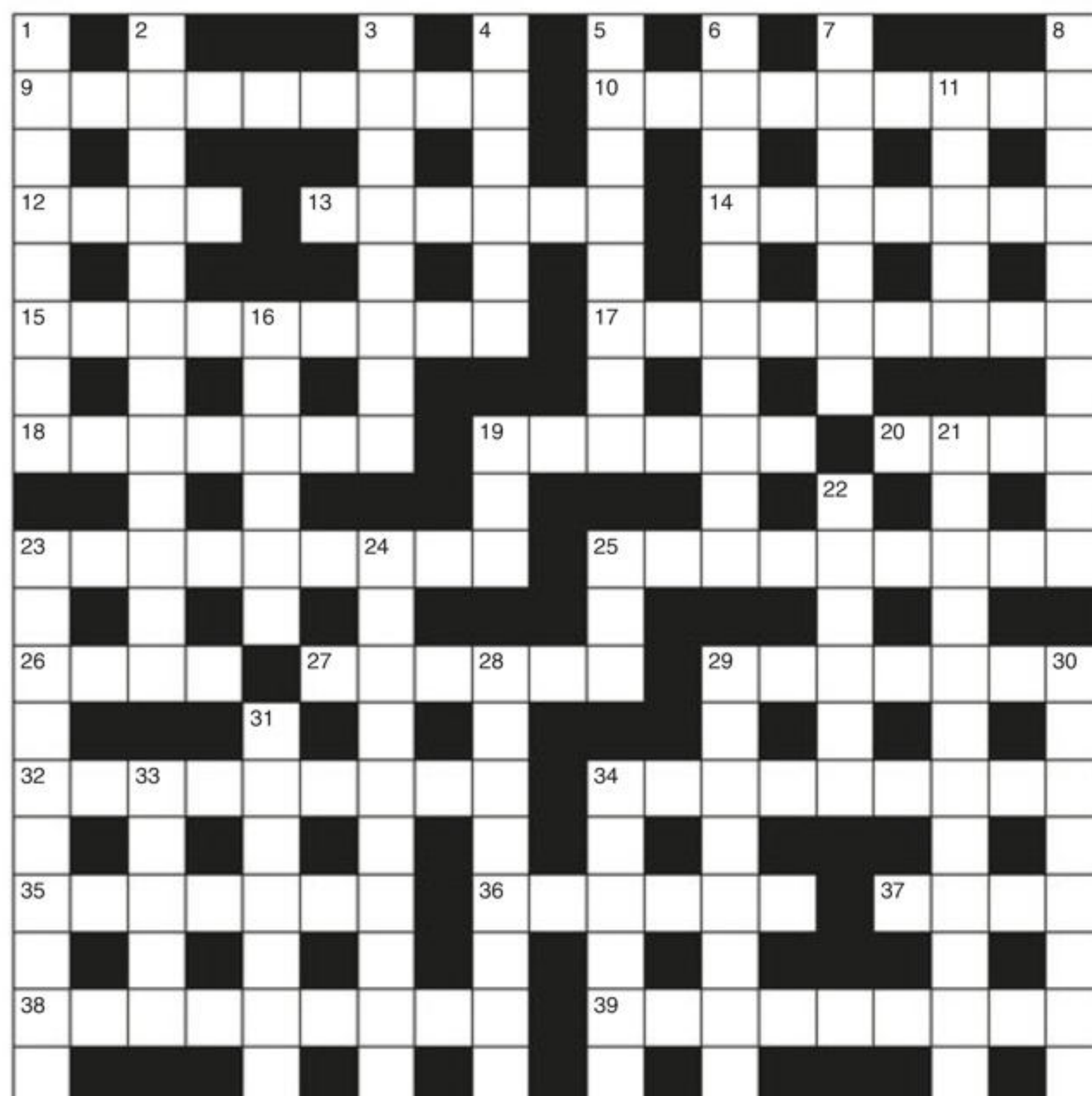
0-3 Heartbroken

4-5 Busting a blood vessel

6-7 A full-blooded champion

EVERY MONTH, A NEW CHALLENGE SET BY AGENT STARLING

Focus crossword N° 142



Solution to Science Crossword No 2



Congratulations to Mr A Campion (Bristol) and Mrs D Saunders (Dumfriesshire), who correctly solved July's puzzle to each receive a copy of *Megacatastrophies* by David Darling.

YOUR DETAILS

NAME:

ADDRESS:

POSTCODE:

TEL:

EMAIL:

Post entries to BBC Focus Magazine, September 2012 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to september2012@focuscomps.co.uk by 5pm on 20 September 2012. Entrants must supply name, address and phone number. By entering, participants agree to be bound by the terms & conditions, printed in full on page 82. Immediate Media, publisher of Focus, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.

Across

- 9 Sent me her pies from astronomer's table (9)
- 10 Rings to get first book on production of eggs (9)
- 12 I return to a tiny amount (4)
- 13 Discover the meaning of length (6)
- 14 Only, as it happens, taking in a mineral (7)
- 15 Answer – leasing a form of relief (9)
- 17 Released flea out of a binder (5-4)
- 18 Direction-finder reaches the limits (7)
- 19 Do gain improvement from certain type of scales (6)
- 20 Repeat in the choir (4)
- 23 Sly chairs' design still in development stage (9)
- 25 Atoms roam about in Mexican city (9)
- 26 One of the elemental constituents (4)
- 27 Article to change with one pen (6)
- 29 Concerning heat in another malfunction (7)
- 32 True Roman solution to a bit of a fraction (9)
- 34 A crop's all ruined by a black hole, say (9)
- 35 Flower shape made of brass (7)
- 36 About to behold notes on a cavity (6)
- 37 Pushing with part of the leg (4)
- 38 Police to work with key part of brain (5,4)
- 39 New rhapsody gets one into uneasy state (9)

Down

- 1 A crisper variety of outer layer (8)
- 2 The WI sent naval officer a butterfly (5,7)
- 3 Old ship gets a new crack team in a state (8)
- 4 A maths problem gets a complaint (6)
- 5 In favour of Milan using a preservative (8)
- 6 Soil expert is mad at moorings (10)
- 7 Organise giant space for defence initiator (7)
- 8 Canine habitat is a misnomer in London (4,2,4)
- 11 Secretly shoot a marsh bird (5)
- 16 Golden Duck initially sank off Baltic port (6)
- 19 Talk of argon, say (3)
- 21 Part of the Sun caught her shop more obliquely (12)
- 22 Old English graduate pursues a male protozoan (6)
- 23 Pet to point people to chain arrangement (10)
- 24 Raising charge after terribly vile rubbish (10)
- 25 Might last 31 days (3)
- 28 Exposes personnel to propeller (8)
- 29 Screening trial involving faulty lace (8)
- 30 Left a gnarly form of air passage (8)
- 31 Subjects include right lines of latitude (7)
- 33 Horse seen in front of Everest (5)
- 34 Awfully cold round university – variable but overcast (6)

Win
A copy of *It's Not Rocket Science* by Ben Miller

The first five correct solutions drawn will each win a copy of *It's Not Rocket Science* by Ben Miller (Little, Brown; £12.99). Entries must be received by 5pm on 20 September 2012.

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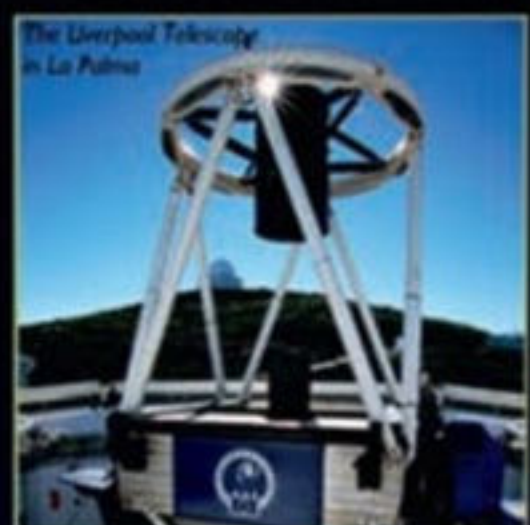
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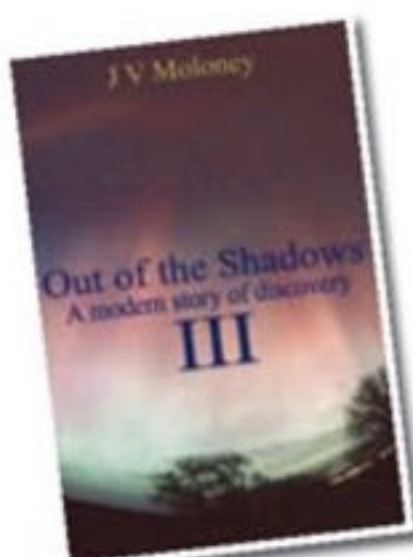
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plus 3 sample chapters
for consideration to:

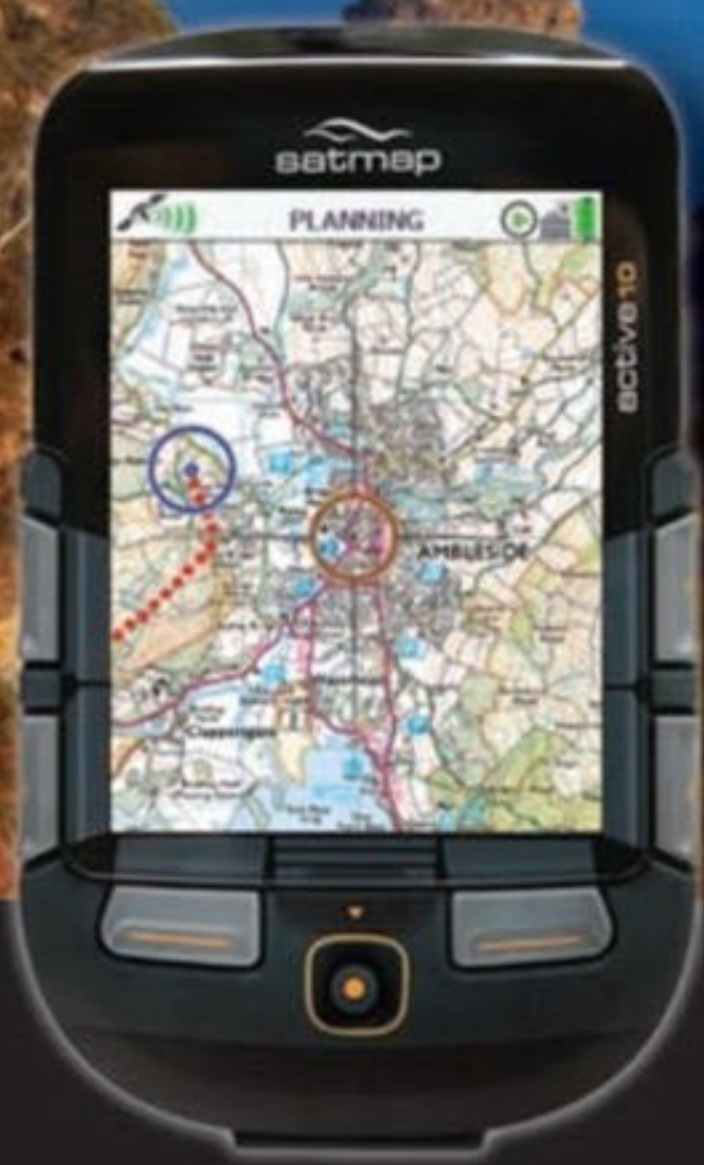
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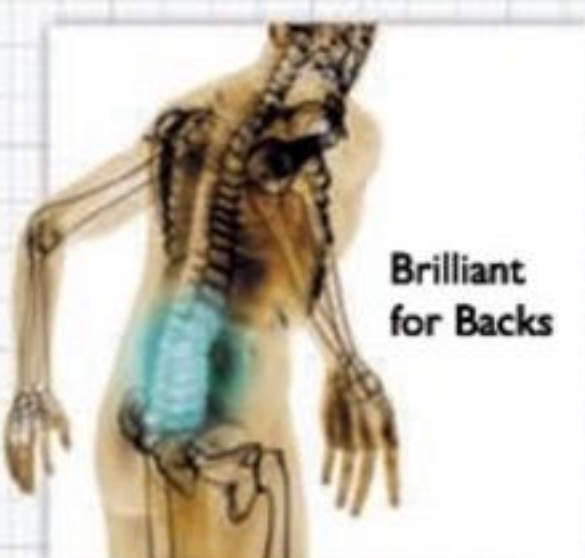
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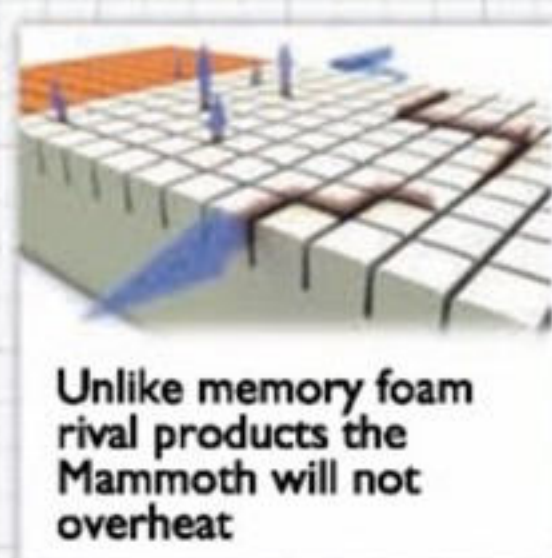


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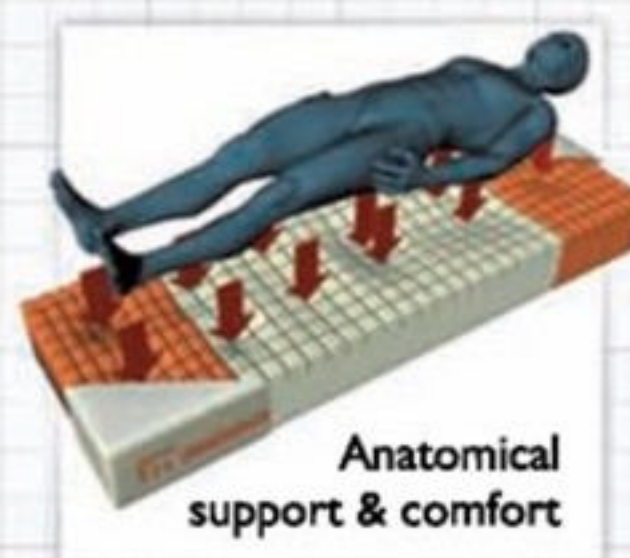
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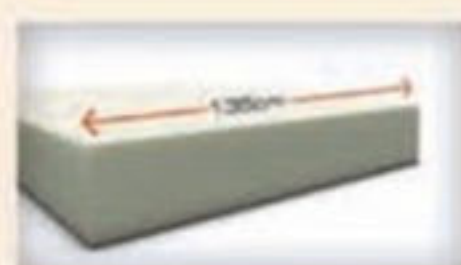
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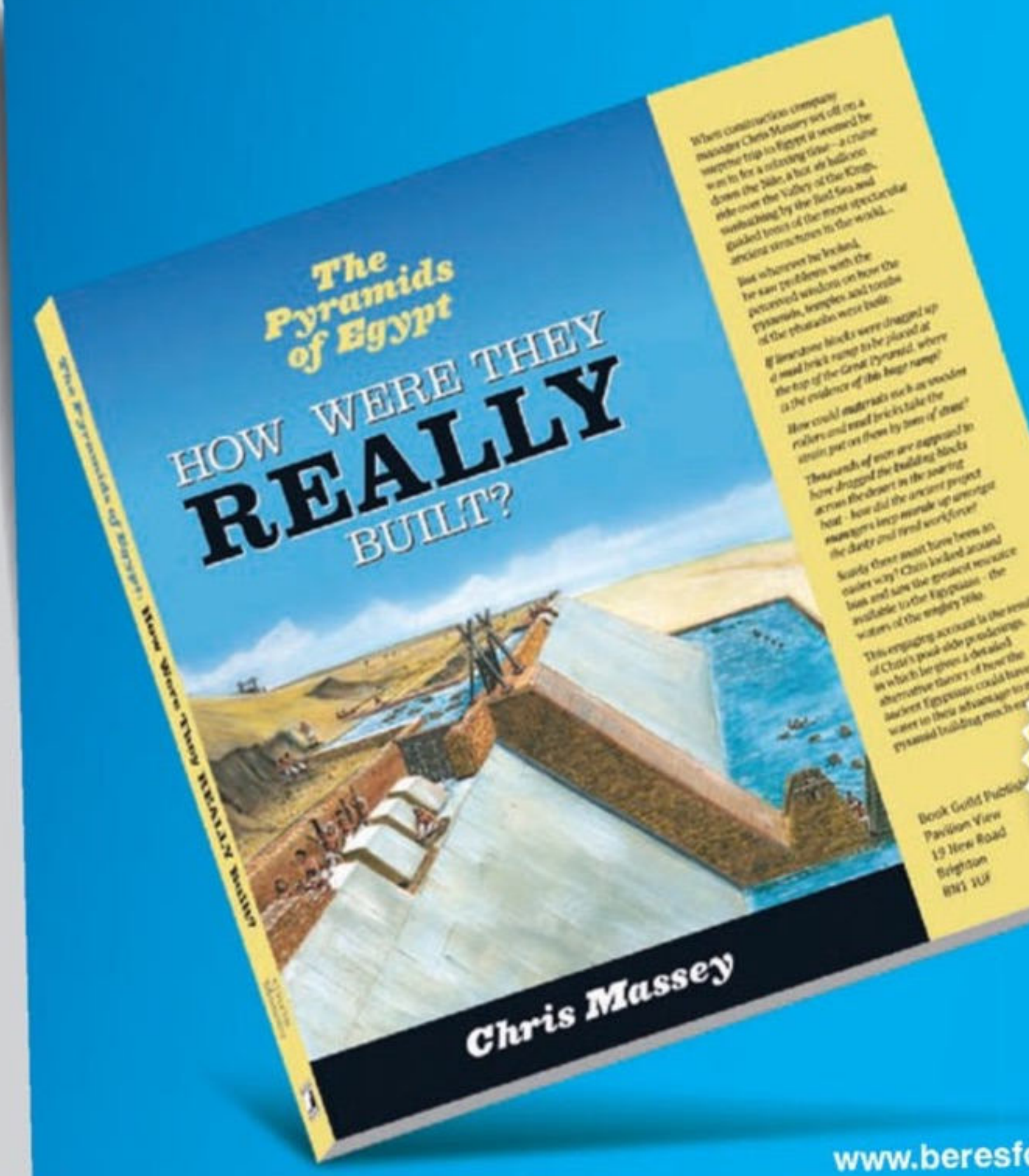
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Then, Now & Next

DNA PROFILING

A British breakthrough has brought many to justice, and the tech is advancing rapidly

WORDS: JAMES LLOYD

◀ THEN

In September 1987, Colin Pitchfork, a 27-year-old baker from Leicestershire, was charged with the rape and murder of two teenage girls. Samples of semen collected from the crime scenes matched samples from Pitchfork and, four months later, he was sentenced to life imprisonment. It was the first conviction made using DNA evidence.

The technology behind this breakthrough was DNA profiling, first demonstrated by the geneticist Alec Jeffreys in 1984 (pictured). Working at the University of Leicester, a few miles from where Pitchfork committed his crimes, Jeffreys found a way of manipulating DNA to obtain genetic 'fingerprints' that are unique to every human except for identical twins. The technique involved looking for 'minisatellites' – repetitive sections of DNA that are highly variable between individuals. By detecting lots of minisatellites, he was able to create barcode-like patterns that could be used for identification purposes. It wasn't long before the world realised the implications for crime investigation, paternity testing and immigration disputes.

|| NOW

The technique that brought Pitchfork to justice is now largely obsolete. Instead, forensic scientists use a process called the polymerase chain reaction (PCR) to amplify small, repeating sequences of DNA. These 'short tandem repeats' are considerably shorter than minisatellites, making them quicker and easier to analyse.

The powerful ability of PCR to amplify tiny amounts of DNA allows scientists to work with much smaller and more degraded samples. "The sensitivity of the earlier

systems was around a few thousand cells' worth of DNA," says Sir Jeffreys. "With PCR, you can in principle get right the way down to the level of a single human cell." Armed with the latest techniques, forensic scientists are now revisiting DNA evidence from older crimes. The Innocence Project in the US uses profiling technology to help clear the names of wrongly convicted people. Since 1992, nearly 300 prisoners have been proven innocent, including 17 who had served time on death row. In about 40 per cent of these cases, DNA profiling also allowed the real perpetrator to be identified.

▶▶ NEXT

Rather than make do with small sequences of DNA, forensic scientists of the future might analyse someone's entire genome – their complete set of DNA – to tease out extra information. The completion of the Human Genome Project in 2003 kick-started a revolution in DNA sequencing, with a multitude of companies offering to sequence individual genomes. "We are virtually at the point of the \$1,000 genome," says Jeffreys. When this milestone is reached, genome sequencing will become ever more

widespread. One area of research is looking at the possibility of linking differences in people's genomes to their physical characteristics. For instance, it might be possible to use DNA collected from a crime scene to predict a suspect's eye colour, race, sex, or maybe even their facial features.

"Predicting facial features is still in the realm of science fiction at the moment," says Sir Jeffreys. "But some tantalising leads are beginning to emerge." ■

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